Iron and Steel ENGINEER

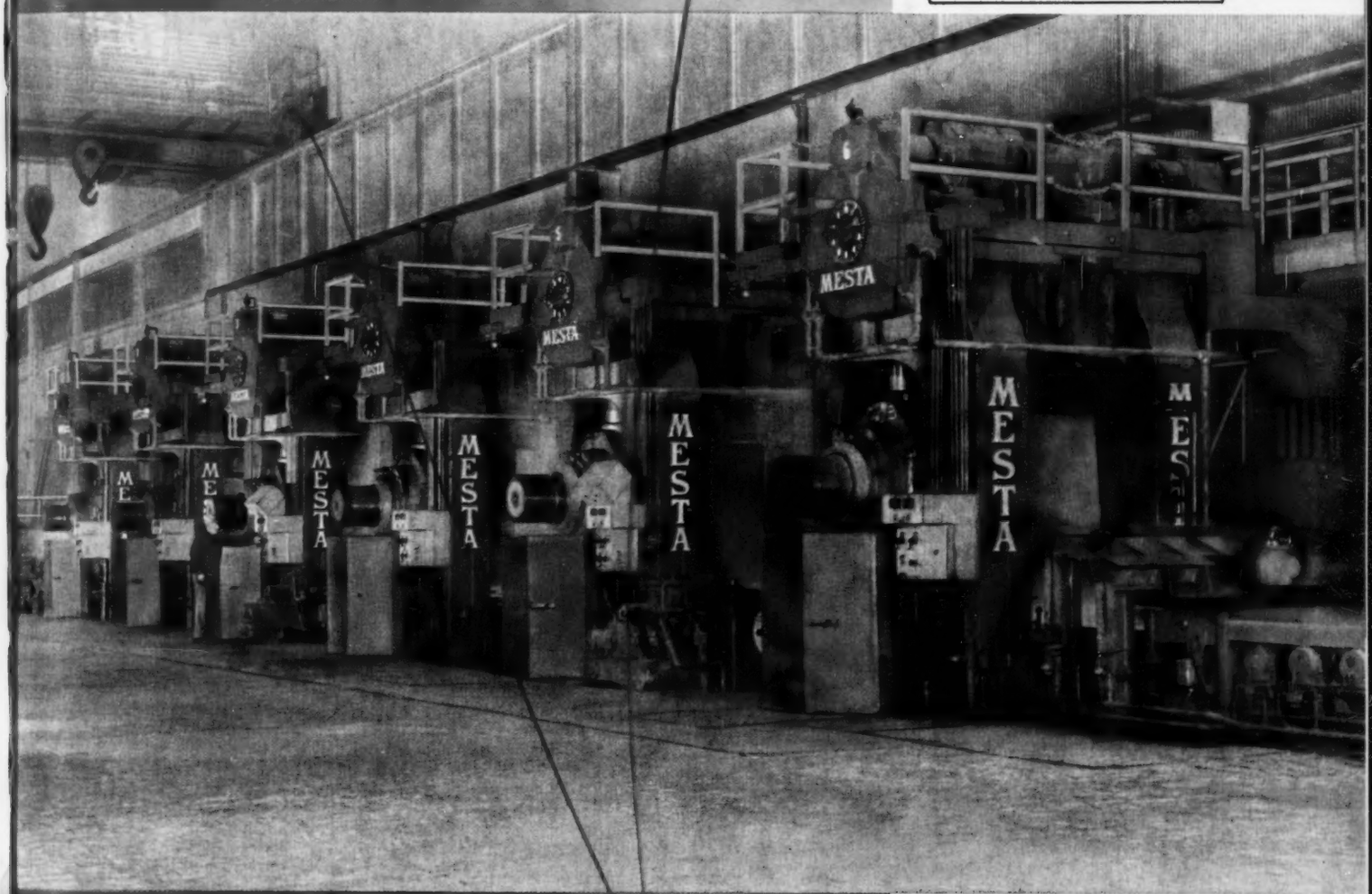
ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

OCTOBER 1961

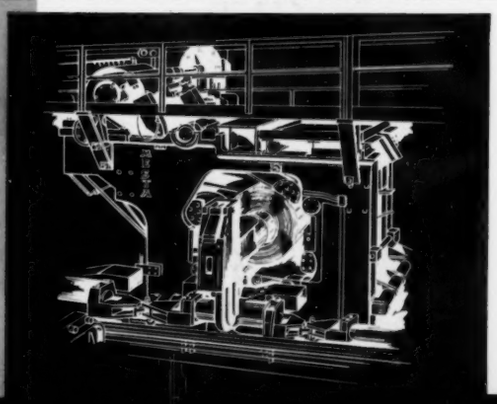
DESIGNED AND BUILT BY

MESTA

HOT STRIP MILLS



Six Finishing Stands with Three Vertical Edgers on the MESTA 44" Four-High Hot Strip Mill at Jones & Laughlin Steel Corporation, Aliquippa Works



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MESTA MACHINE COMPANY

PITTSBURGH, PENNSYLVANIA

Painting by Jack Kraft

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upon its ability to flex its muscles to outpoint competition. A vigorous industrial competitor, ALLIANCE developed its physique through years of research and engineering, manufacturing skill, product performance and dependability. It pledges to remain strong: in purpose . . . in integrity . . . in service . . . and in producing the greatest overall return on each customer dollar invested.

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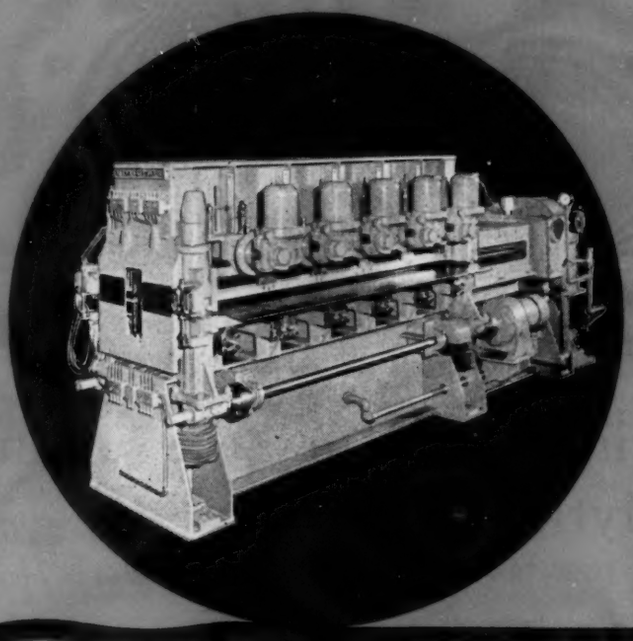
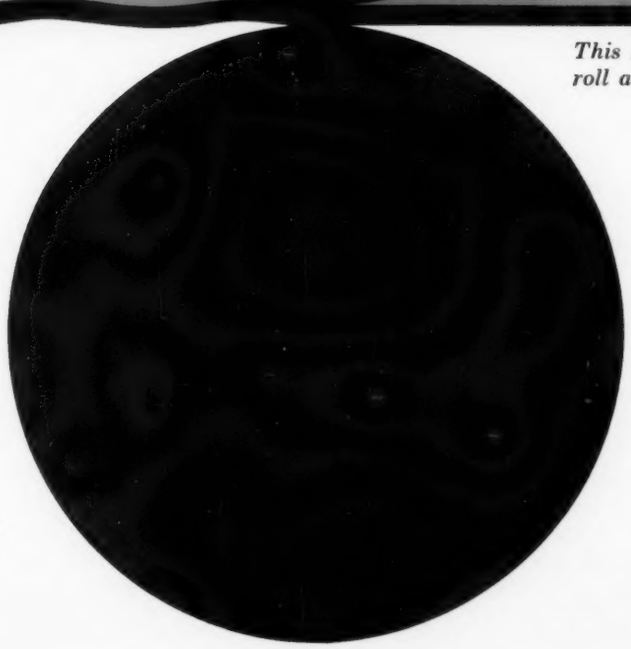
What kind of roller leveler do you need for your particular product? Want high speed? We have high speed levelers. Want an economical model for less demanding work? We have one of the best models in the business. Want a quick opening head? We have either hydraulic or motor-operated or hand-operated models. Want centralized lubrication? We equip all levelers with centralized lubrication with the exception of a few models. Want antifluting? We have it. Want individual adjustment or centralized adjustment? We have both types. Want more roll life per redressing? All of our rolls are induction hardened. Want an existing leveler reconditioned? We have an efficient service setup. What size leveler do you need — 1⅛" up to 18" diameter work rolls? We make all sizes and types. In fact, the Aetna-Standard Division of Blaw-Knox is one of the major manufacturers of Roller Levelers. For information, write to Sheet and Strip Sales, Aetna-Standard Division, Blaw-Knox Company, 300 Sixth Avenue, Pittsburgh, Pennsylvania.



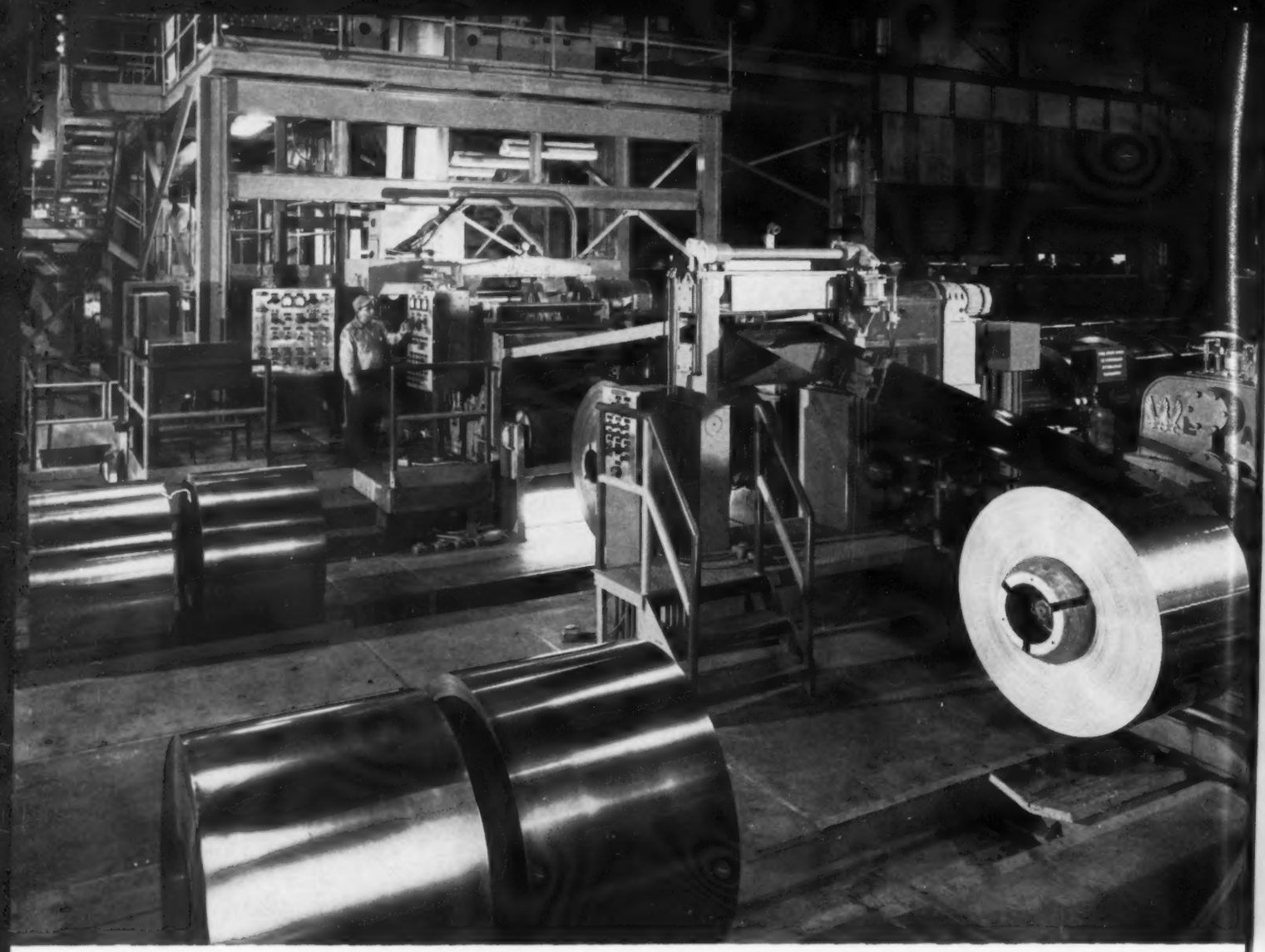


This Roller Leveler has individual motor-operated backup roll adjustments. 1¾" dia. x 72" face . . . 21 rolls.

BLAW-KNOX

Aetna-Standard Division

BLAW-KNOX



Columbia-Geneva Steel increases tin plate production with third Wean Electrolytic Tinning Line

A third Wean Electrolytic Tinning Line was installed recently by Columbia-Geneva Steel Division of United States Steel Corporation to meet the growing demand for high-quality tin plate on the West Coast. This high-speed "Ferrostan" line incorporates the most modern engineering advances in design and construction of continuous processing lines.

This modern line is among the first to employ an electronic data-logging system to provide a "process profile" of all coiled tin plate. Other new features include improved conductor roll mountings for more rigid support, easily replaced cartridge seals for submerged rolls, and air cylinder-controlled hold-down rolls for faster, more convenient adjustment.

Exit end equipment provides for both recoiling and shearing. A pay-off reel is included to permit shearing and classification of finished coils while the strip being processed is recoiled.

Fifty-one of the world's electrolytic tinning lines carry the Wean name and process over 80% of all electrolytic tin plate produced today. Wean's pioneer experience in continuous processing line equipment has served every major steel firm during the past thirty years. Wean's experience and "creative engineering" stand ready to serve you.

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"Big Pearl" wanted her billets hot and fast!

THE ANSWER: A Plibrico Lined Car-Bottom Furnace

. . . and Plibrico helps Gulf Forge open up a new large forgings market!

Here's the story . . .

PROBLEM: "Big Pearl", an 804,000 pound Mesta forge, was losing production, standing idle and waiting because old, side door batch furnaces were too slow with billets. Gulf Forge's plans to enter the large forgings business were threatened.

SOLUTION: A completely new Plibrico designed, engineered and installed car-bottom furnace. Sides, roof, guillotine door lined with Plibrico Super "F" plastic refractory. Car top lined with Plicast "31" castable refractory. Completely monolithic.

RESULT: "Big Pearl" gets all the hot billets she can handle —"ala carte." Gulf Forge makes larger forgings at a nice profit and has broken into a big market closed to it before.

PLUS: In 2½ years of steady operation *no repairs at all* to the interior of the furnace. This because Plibrico Super "F" withstands both thermal and mechanical shock at operating temperatures from 2200 to 2800°F. Only minor repairs to the car-bottom lining. Furnace downtime cut to a minimum.

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gives advantages, characteristics for foundry, steel mill, industrial applications.

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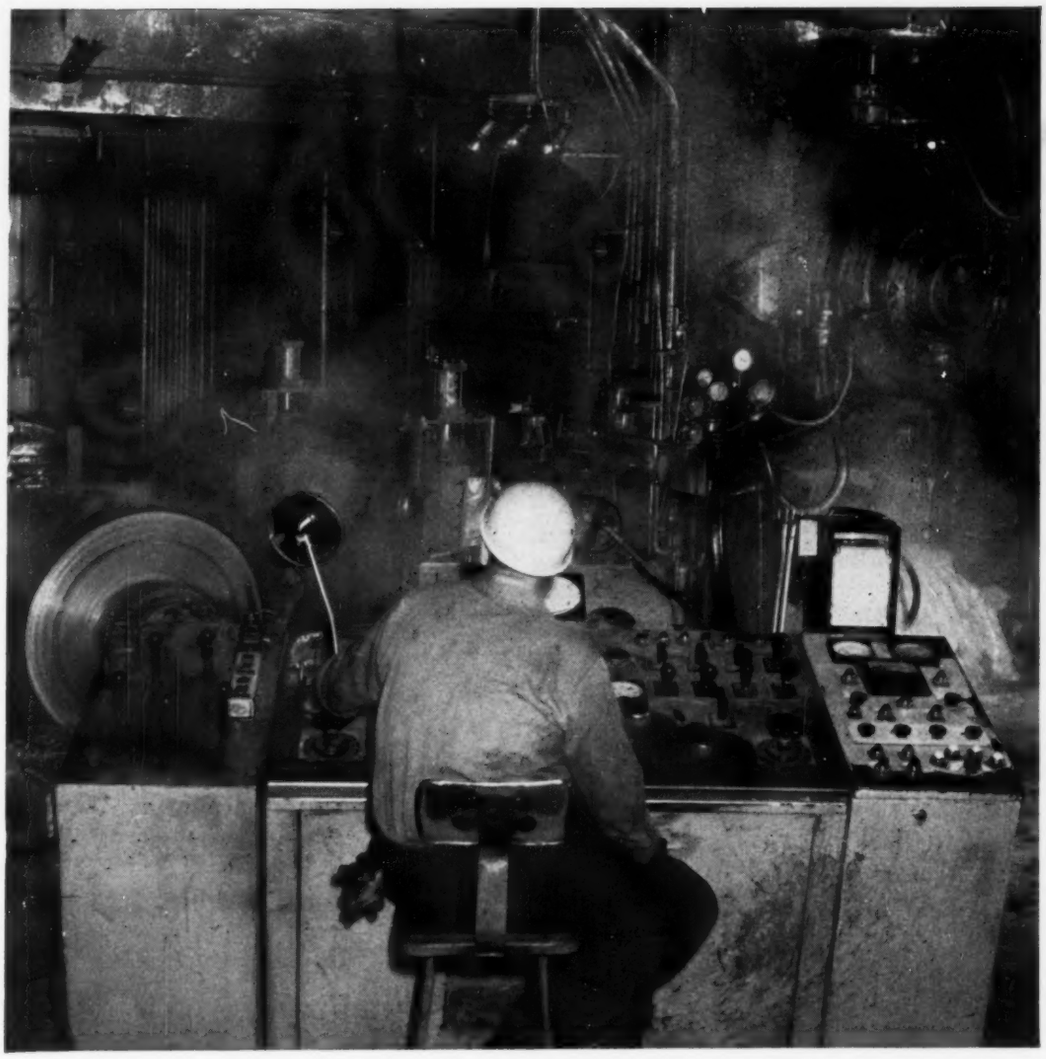

56-inch 4-High
Cold Reversing Mill
at Dominion Foundries
and Steel Limited,
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which is equipped
with the Davy-United
system of Automatic
Gauge Control. This mill
rolls steel strip for
tin plate between 24 inches
and 50 inches wide
in a range of thicknesses
from .006 inches to
.050 inches.

Six Automatic Gauge Control installations have now been completed or ordered in North America and Licensees in North America for the Davy-United system of Automatic Gauge Control include General Electric Company of the U.S.A., Canadian General Electric Company Limited and Canadian Westinghouse Limited.

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IF YOU WANT SUPERIOR PRECIPITATOR PERFORMANCE

A precipitator is a lifetime purchase. Once it is installed, you must live with it, whether you like its habits or not. Because of that Buell urges you to look for the following features when you are making the major investment represented by an electric precipitator.

CONSTRUCTION

1. Custom designed, flexible—Buell helps you determine your precipitator needs, then designs a unit specifically for your requirements. Since Buell SF Precipitator sizes change by only 16" increments, you can get exactly the size you need, without compromise of size, space, and cost.

2. Simplified erection—Modern construction and assembly-marked components and a design that facilitates simple installation, make Buell SF Precipitators easy to erect without specialized contractors. Erection is supervised by Buell engineers, to ensure satisfactory operation.

3. Rugged construction—Simple, rugged construction gives you high efficiency, combined with negligible maintenance costs.

GAS FLOW

4. Uniform gas distribution—Buell designs the entire gas system for its precipitators—including connecting flues with adjustable turning vanes if needed. In addition, at the inlet, special field-adjusting baffles ensure uniform flow across the entire face of the unit. Buell has complete laboratory facilities to determine dust or gas flow pattern with specially constructed three dimensional precipitator models.

ELECTRICAL SYSTEM

5. Fool-proof power supply—Buell silicon rectifiers are compact, lightweight, highly efficient. They need no maintenance—another reason for the top performance of a Buell SF Precipitator.

6. Rigid suspension—The emitting frame of a Buell SF Precipitator is hung from four temperature and shock resistant quartz insulators, each sealed in an individual heated compartment. With this rigid system, electrical distance from emitting to collecting electrode is held constant. This produces uniformly high emission for peak efficiency.

7. Peak emission—Exclusive Spiralectrode® emitting electrodes are fixed top and bottom to the emitting frame. Self-tensioned and permanently aligned, they present areas of maximum emission per unit of power input. Top emission can be maintained with maximum applied voltage, because Spiralectrodes eliminate misalignment.

8. Minimum maintenance—The common maintenance headache in most precipitators is frequent replacement of emitting electrodes. Because of rugged suspension and patented electrode design, Buell's 10-year replacement record in this critical area is under 2%.

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9. Effective rapping—avoids reentrainment—Buell mechanically raps one row of electrodes at a time, in a continuous cycle. Special pockets in collecting electrodes, and section-by-section rapping in the direction of gas flow, ensure against reentrainment.

You're sure to be pleased with the superior performance and minimum maintenance you'll get with a Buell SF Precipitator! Buell Engineering Co., Inc., Dept. 60-J, 123 William St., New York 38, N. Y. electric precipitators · cyclones · bag collectors · combination systems · classifiers. **Member Industrial Gas Cleaning Institute**

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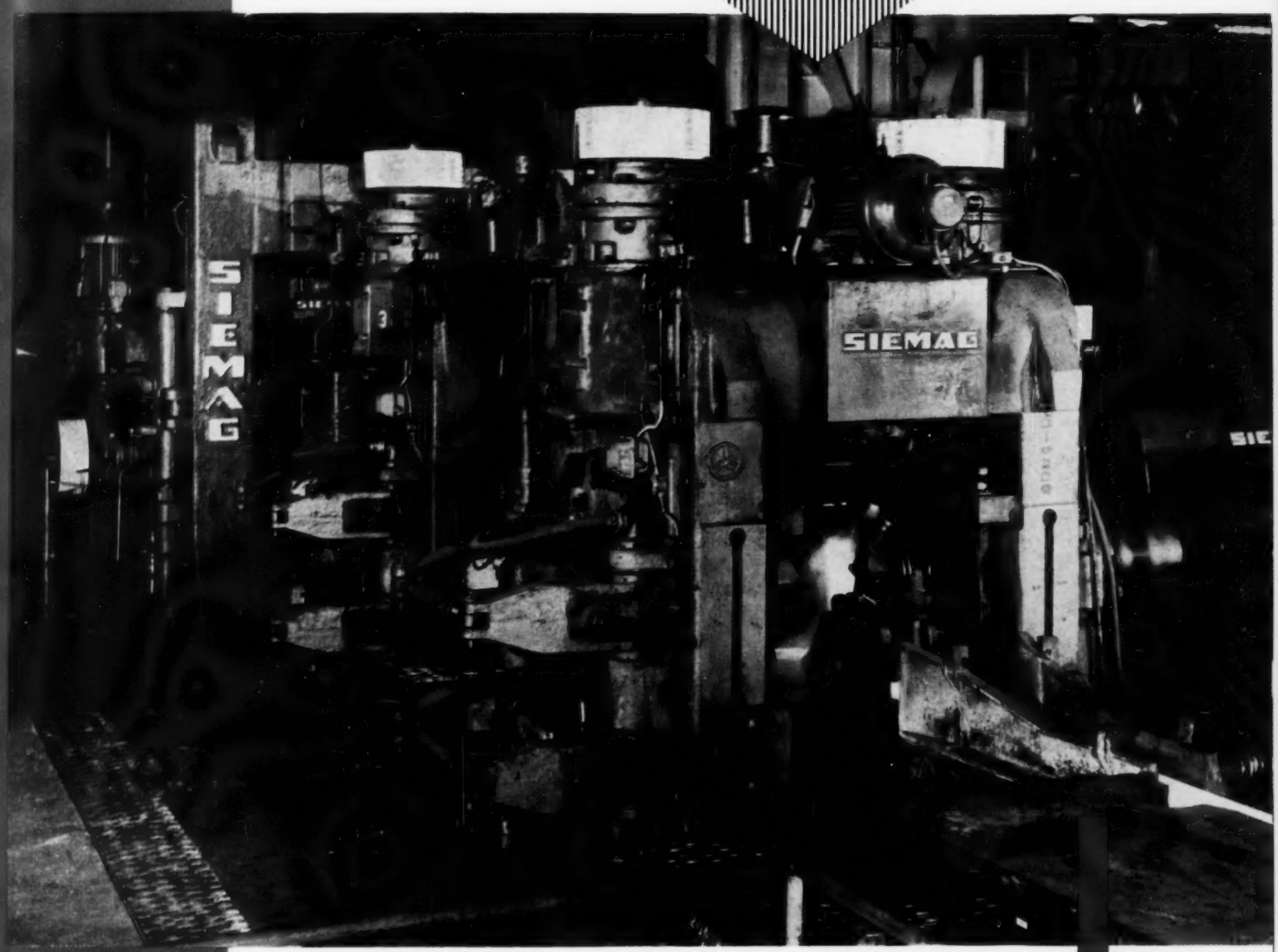

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WAGNER® HYDRAULIC CRANE BRAKES *help speed cargo handling*

There are four Wagner® Hydraulic Crane Bridge Brakes aboard Inland Steel Company's S. S. EDWARD L. RYERSON. Specially engineered for high holding torque, they are used for parking and holding the gantry crane that handles the ship's hatch covers. These four Type HM 6″ x 3″ brakes are all operated from one station . . . make it possible to open hatches with the speed and safety that results in faster handling of cargo.

Wagner Hydraulic Crane Bridge Brakes can increase the productivity of your operation, too. They stop cranes accurately and smoothly . . . so important in operations where frequent starts and stops are necessary; where close spotting is required; where heavy equipment is involved.

These proven industrial crane bridge brakes are increasing production rates in other applications:

- **Emergency stopping of machinery**
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- **Special power braking**

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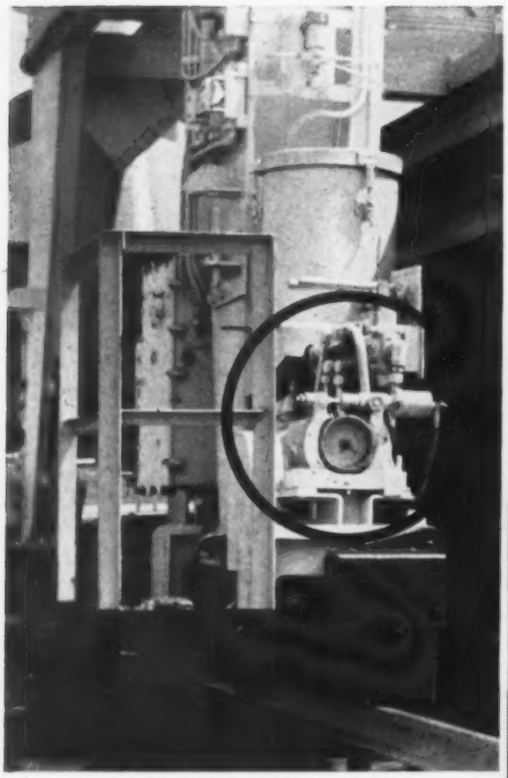
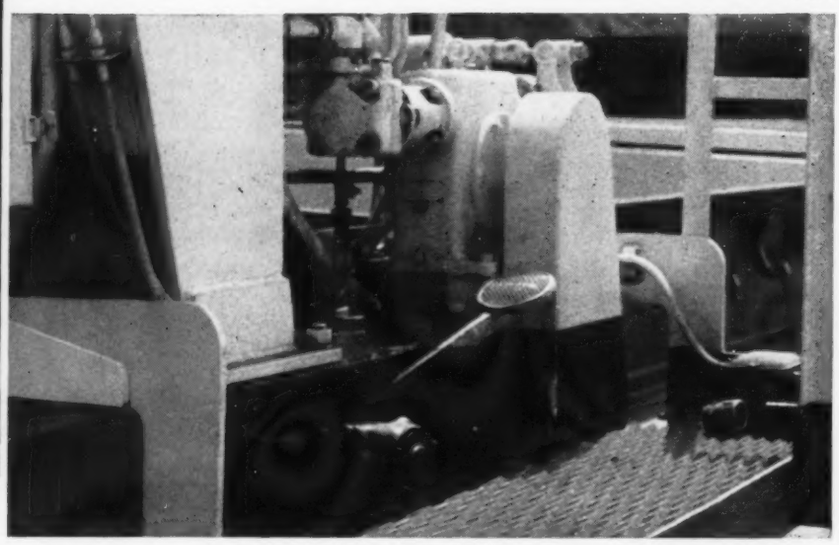


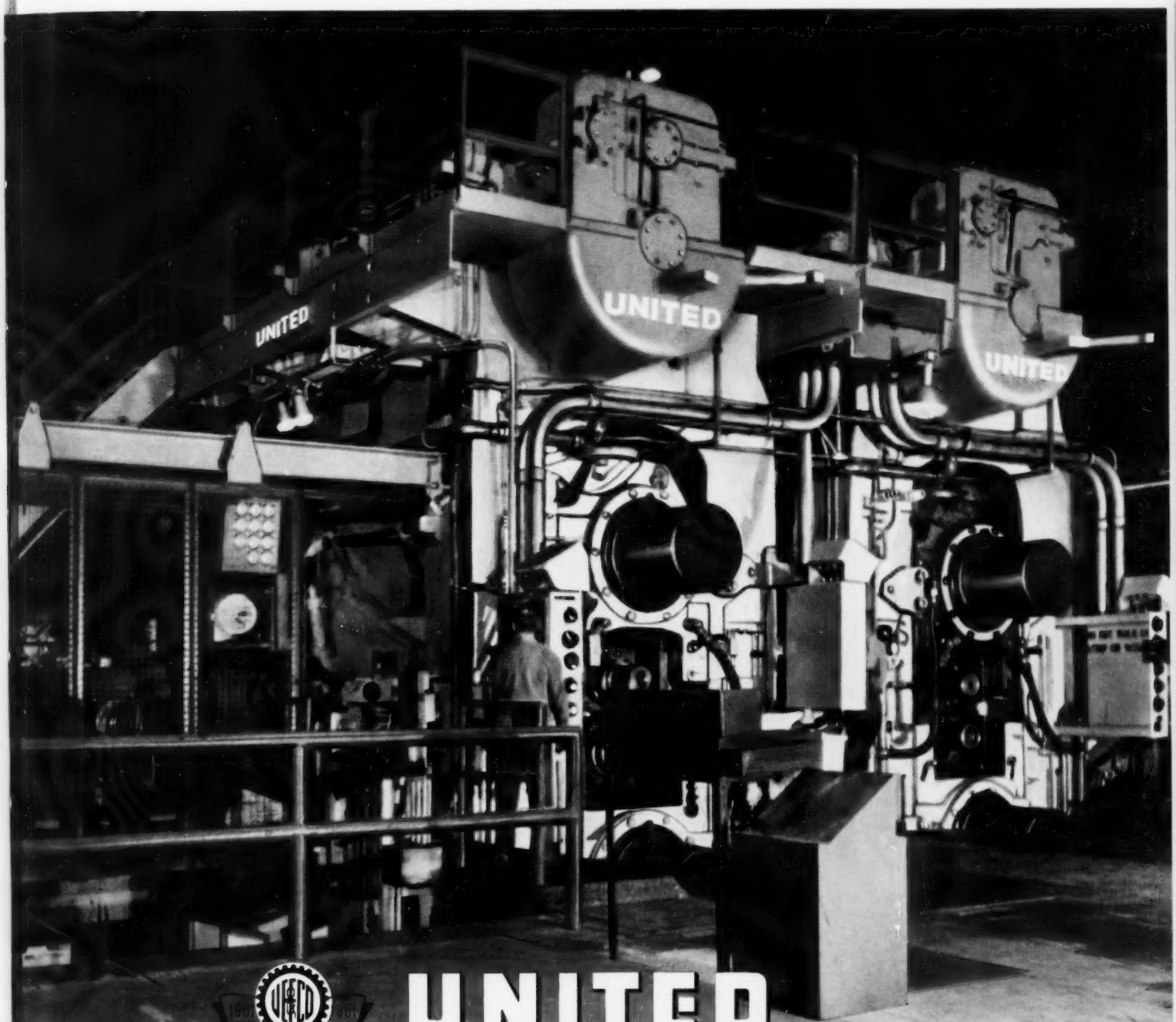
One of the four Wagner type HM hydraulically operated service brakes, with spring-applied parking means, that help speed the opening and closing of the hatches to minimize "hold-up" of the ore boat at the dock.



All four Wagner brakes on the S. S. EDWARD L. RYERSON'S gantry crane are operated from this single station.

UNITED®

4-HIGH 2-STAND TANDEM TEMPER PASS MILL



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Crops *and* Shorts

△ Free enterprise! It is wonderful.

As the steel industry takes on added labor costs stemming from the government encouraged settlement of 28 months ago, it is met with a barrage of threats as to what might happen if they raise prices. The fact that many companies are not making enough to cover dividend payments is ignored completely. Senator Kefauver threatens to investigate the industry if prices are raised. Senator Gore threatens to break up the larger companies into several smaller companies if prices are raised. President Kennedy spoke of "restrictive monetary and fiscal measures." His letter to steel company executives said that a price increase would shatter the country's present stability. It further intimated that foregoing a price in crease should moderate labors demands next year. On the heels of the president's letter came a blast from David J. McDonald, president of the United Steel Workers of America, gloating over recommendations to be made by the President's Council of Economic Advisers and renewing his desire for a 32-hr work week and sabbatical years.

Steel company replies were, in general, couched in polite terms but unanimously reserved the right to raise prices if it should be necessary for the financial stability of the companies.

We rather like the sentiments of Max A. Zivian, president of Detroit Steel Corp., who feels that, if Mr. Kennedy wants to freeze prices, he should also freeze wages.

△ With a total attendance of about 3000, the 1961 convention of the Association of Iron and Steel Engineers seemed to attract more than usual interest. Standing-room crowds at most of the sessions attested to the numerous comments concerning the excellence of the technical program. About 462 men made the trip to Butler to see the Armco Steel plants there. Among the registrants were men from Canada, Britain, France, Sweden, Japan, South America and India.

A European now with the United Nations expressed wonder at seeing so many mature men listening intently to the technical papers. He said that European engineers go through school, perhaps to a doctorate degree, and then stop learning.

△ Reports from Russia announce a new capacity goal for the iron and steel industry of 275,000,000 net tons by 1980. The previous goal was 220,000,000 tons by 1985. The present capacity is 77,000,000 tons. The increase will be made by raising the capacity of existing plants by 50 per cent and building new plants east of the Ural Mountains, where 180,000,000 tons will be located by 1980. They hope to exceed the per capita production of the United States by 1972.

△ Logan T. Johnston, President of Armco Steel Corp., told trade paper editors that the specialty steel of today becomes the commodity of tomorrow. Exemplifying this is aluminum-coated steel sheet, developed at Armco's Butler works. Armco's present capacity of 75,000 tons per year of aluminized sheet lies in two coating lines at Butler. A new line of 100,000 tons annual capacity is to be built at the company's Middletown works.

△ The *Wall Street Journal* observes, what with the increasing number of women holding down jobs, man will soon be earning his bread by the sweat of his frau.

△ Negotiations are under way for two new blast furnaces in Southern Rhodesia, to be built co-operatively by Kawasaki Steel Corp. and Rhodesia Iron and Steel Co. Most of the iron production, as well as some iron ore, is to go to Japan.

△ Continuing its search for iron ore, the Japanese steel industry has two missions in Brazil on the invitation from Companhia Vale do Rio Doce, the state-owned company with mines at Itabira. Also, the state-owned Cia. Siderurgica Nacional has offered to trade iron ore for steel ingots. In New South Wales, test drilling is under way to determine the suitability of iron and copper ores. Some Siberian ore has been purchased from the Soviet Union but impurities and relatively low-iron content may preclude continuation.

△ A correspondent sent us this study in homonyms: Vacation consists of two weeks which are too short, after which you are too tired to return to work and too broke not to.

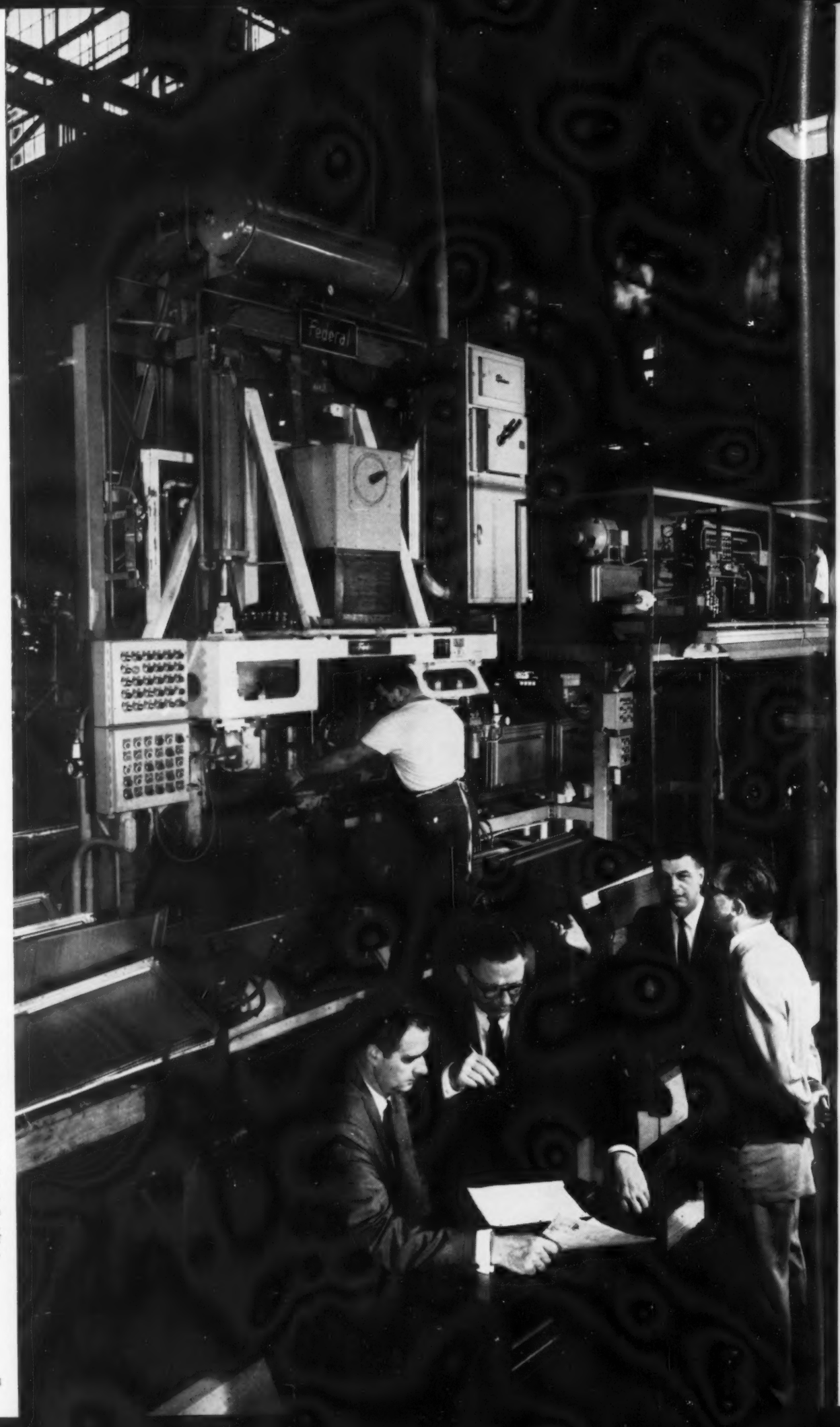
△ A recent publication of the United States Department of Commerce criticizes American business for its approach to foreign business. It says that when a German firm gets an inquiry, a representative calls on the prospect the next day. A British representative will follow up an inquiry the following week. But an inquiry to an American firm might not be followed up by a representative for months, if ever.

△ A recent news-letter from a brokerage house used a (to us) brand new word: "floccinaucinihilipilification," which the letter defined as "the habit of estimating as worthless." The word is not in our dictionary—maybe it is in yours.

△ Although compact cars now make up more than one third of the automobiles produced, manufacturers continue to harp on the fact that many of these are "dolled up" and are not economy cars. Shouldn't they begin to realize that there is a demand for well-designed, well-built cars with good performance but somewhat smaller than the misshapen monsters they have been making?

△ The Office Economist says a conference is a meeting at which people talk about what they should be doing.

△ Approximately 230 people representing the Iron and Steel Institute (of London) will tour the United States and Canada between October 18 and November 9. The program includes visits to 14 steel plants, six research laboratories and one football game.

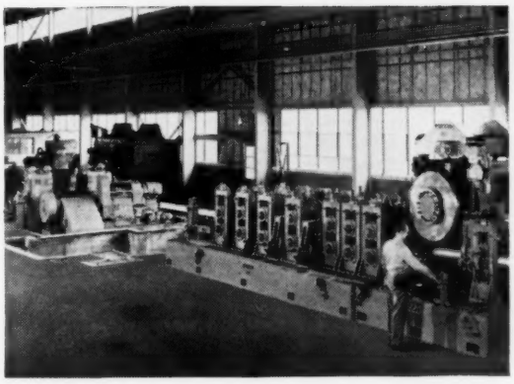


Federal Welding Line at Whirlpool's Evansville, Indiana, refrigerator plant automatically forms and welds together complete food liner shells at a rate of 200 per hour. Here, F. A. Bodenheim, Jr., manager of welder sales for McKay's Federal-Warco Division, goes over latest production charts with H. J. Muehlbauer, director of manufacturing engineering for Whirlpool, as Robert Bussell, sales representative for Federal-Warco, discusses operations with Gene Rommel, general superintendent of tooling for Whirlpool.

Photo by ARNOLD NEWMAN

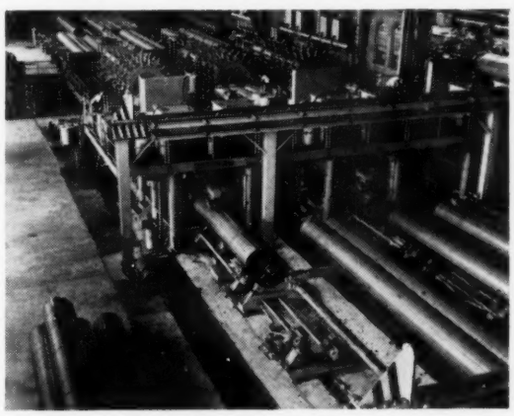
A completely integrated plant . . . a single source of supply . . . one area of responsibility! A new idea? Not really, but an idea that's not easy to bring to reality. McKay Machine has done it for metal fabricators, designing and building equipment to volume produce parts or entire units from raw steel to finished product. ***This is McKay Machine*** We know steel handling . . . we've been designing uncoilers and coil-handling equipment for 30 years. McKay Machine knows welding because the highly respected names of Federal Welder and Berkeley-Davis are now a part of our company. We know processing and forming . . . McKay levelers, tube mills, and cold roll forming machines have been specified by leading industrial firms for more than two decades. And McKay Machine knows stamping, as the Warco Press name testifies. McKay builds the industry's most popular shearing and slitting equipment. Only McKay Machine designs and builds all the components for a truly integrated production line. If you are one of the hundreds of manufacturers who must shave production and handling costs to successfully compete, McKay Machine should interest you. If we do, let us know and we'll meet with you at your convenience. *The McKay Machine Company, Youngstown 1, Ohio.*

McKAY MACHINE



McKay Tube Mills and roll forming machines are considered among the best engineered in the world.

Warco Presses can be found in the leading automotive, appliance and aircraft plants . . . wherever stamping is a major operation.



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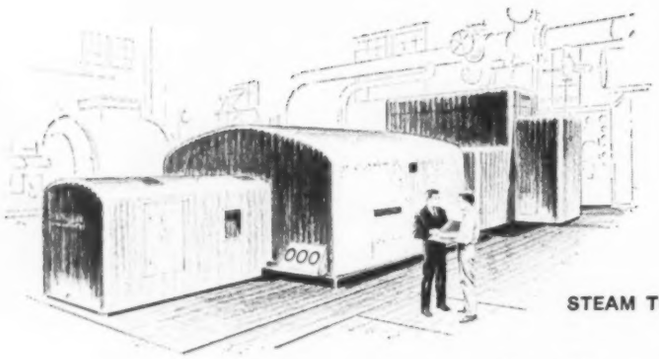
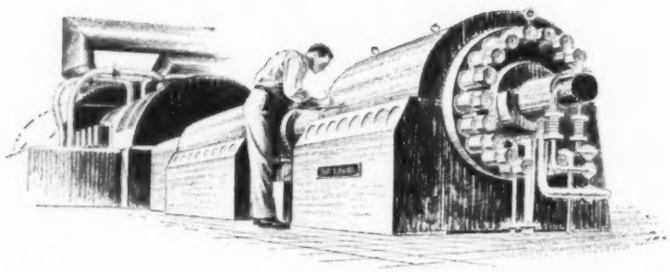
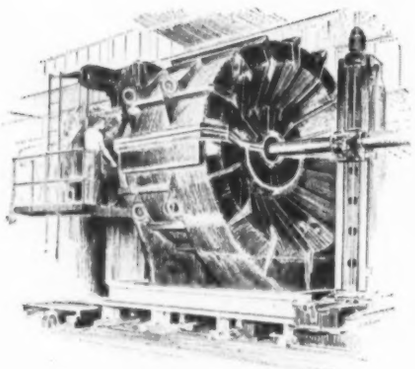


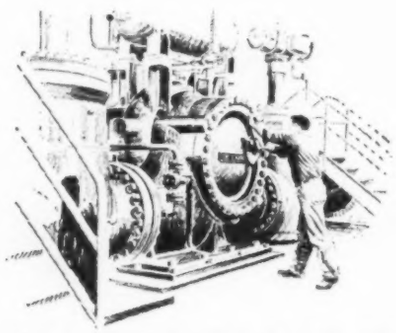
STEAM TURBINES



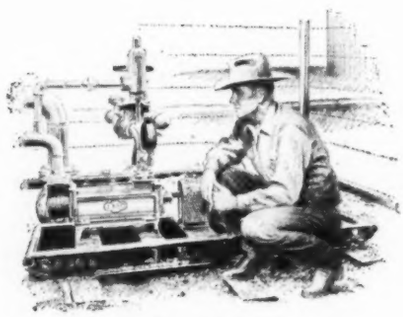
CENTRIFUGAL PUMPS



BLAST FURNACE BLOWERS



SINGLE- AND MULTI-STAGE COMPRESSORS



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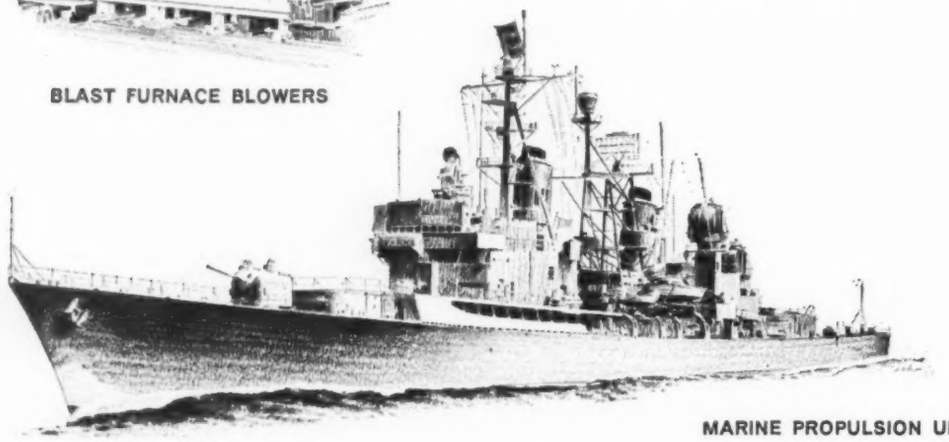

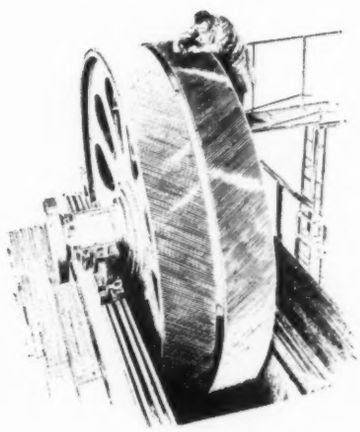

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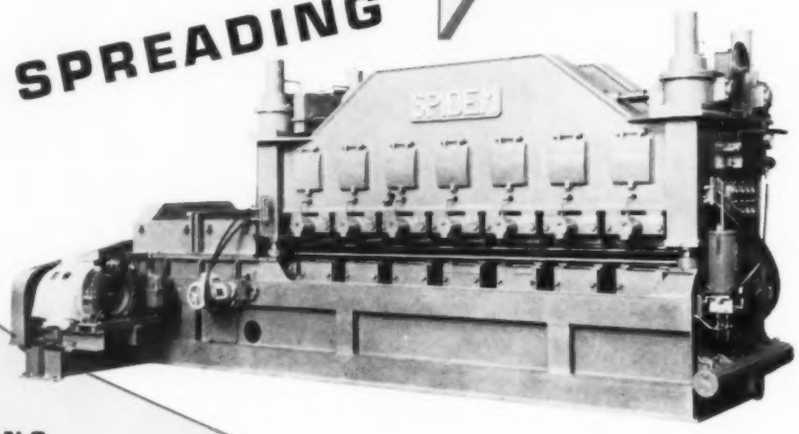

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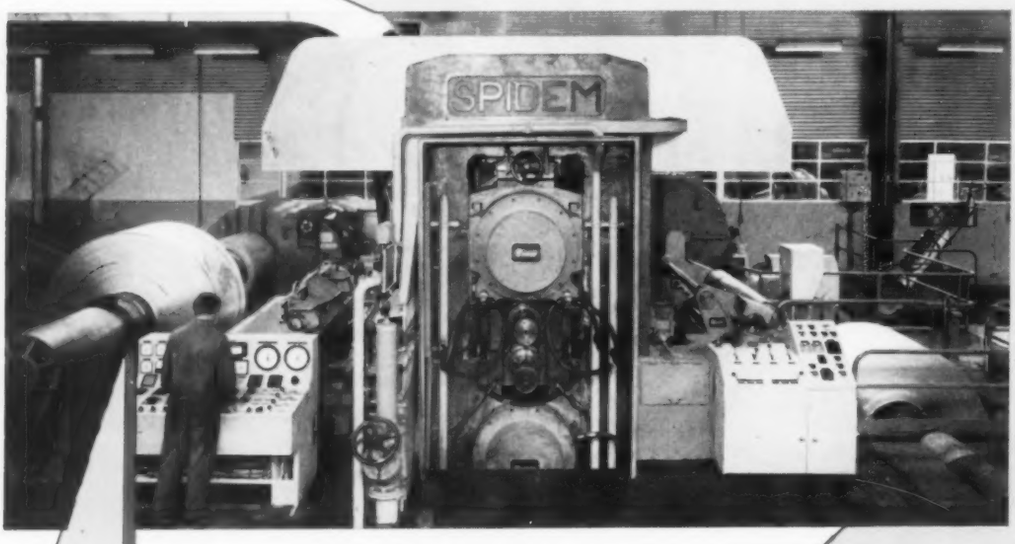

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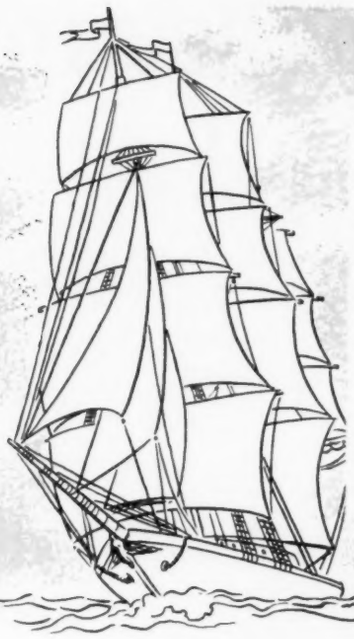

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The original Rust-Oleum formula was developed nearly fifty years ago by Sea Captain Robert Fergusson, who became intrigued with the rust-stopping qualities of fish oil early in his career. Creating a *special treatment* for the fish oil, he used the *specially-processed fish oil* as the vehicle in combination with fine rust-inhibiting pigments. The result? A coating that actually *stopped rust* when applied directly over sound rusted surfaces, after scraping and wirebrushing to remove rust scale and loose rust. Possible, because the *specially-processed* fish oil penetrated the rust to bare metal. This was the birth of Rust-Oleum's *exclusive* 769 Damp-Proof Red Primer.

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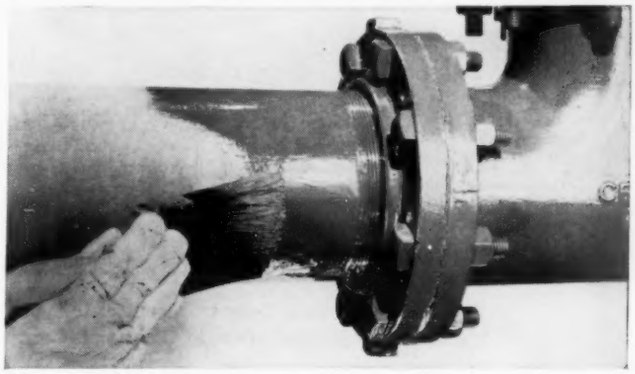

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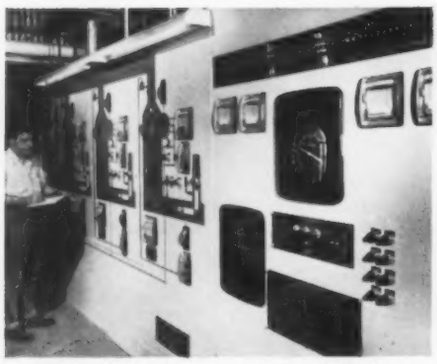
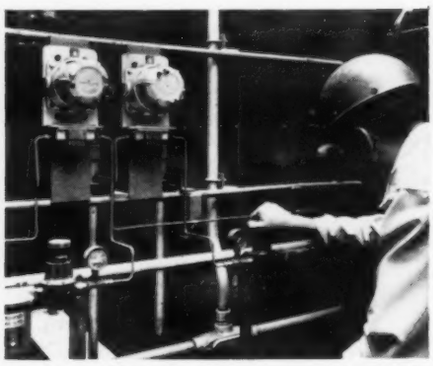
Foxboro Electronic Instruments

Foxboro's Electronic Consotrols control four precipitators from this central panel for Jones & Laughlin's big smoke abatement system in Cleveland. Contracting Engineers: Loftus Engineering Co.



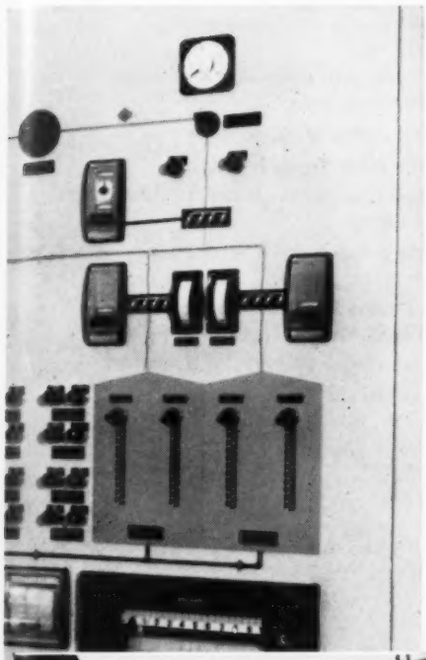
Waste heat boiler control panel includes Foxboro electronic controllers, recorders, converters, integrators, and alarms.

Foxboro d/p Cell* Transmitter measures boiler flue draft with an accuracy of ±0.5%.



Foxboro Transducers convert electrical signal from control panel, for controlling dampers.

help curb smoke nuisance at J & L's Cleveland Works



Foxboro instruments assure fast, dependable control for huge smoke abatement system

Foxboro Indicating Differential Pressure Transmitters on precipitator are linked to central control panel by 10-50 ma, d-c signal. Transmitters are completely weatherproof — need no protective housings.

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ELPAR

patent reviews

by MELVIN NORD, Patent Attorney, Detroit, Mich.

Copies of patents may be obtained from the Commissioner of Patents, Washington 25, D. C., at 25 cents . . . . patents reviewed cover period May 23, 1961 to June 20, 1961

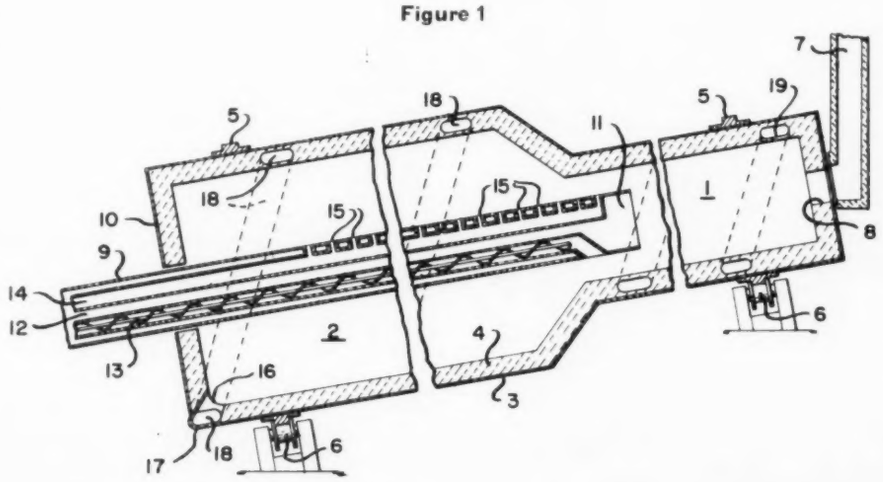
IRON ORE REDUCTION

△ U. S. Patent 2,986,457, issued May 30, 1961 to Arthur J. Jones, provides a method of reduction of iron ores to semi-reduced or fully reduced metal.

As shown in Figure 1, a cylindrical heating chamber 1 is provided, and a reduction chamber 2 of larger diameter than the heating chamber is arranged axially with heating chamber 1. A steel shell 3 and refractory lining 4 are provided surrounding both chambers. The entire assembly is rotatably mounted on tracks 5 resting on flanged rollers 6 and rotatably driven. A flue 7 is provided leading from an opening 8 at the upper end of heating chamber 1. A member 9 projects within the assembly through end wall 10 of reduction chamber 2. The member terminates in a burner 11 which is supplied with a combustible mixture through tube 12, thereby supplying heat to heating chamber 1. Ore and a carbonaceous reducing agent are charged through a screw conveyor 13 to the upper end of reduction chamber 2. Air is supplied through a tube 14 to a series of tuyéres 15 on the upper surface of member 9. An outlet 16 from reduction chamber 2 is covered by a screen 17 through which fully or semi-reduced iron may pass to a hopper. A convolute passageway 18 is formed in the refractory lining 4 and extends from a point adjacent outlet 16 to heating chamber 1 terminating at 19 for return of pellets to heating chamber 1.

Heat absorbent pellets are provided in circulation within the apparatus. The pellets are formed of a chemical inert substance having good heat absorption characteristics. Pieces of refractory are satisfactory for these purposes. As the pellets are deposited in heating chamber 1, they will gradually advance along the length of the heating chamber and will be turned over and intermixed by the rotary action of the heating chamber, having their various faces exposed. The heat supplied from burner 11 will pass in the opposite direction along a length of the chamber and will supply heat to all of the pellets. As the pellets reach the end of heating chamber 1, they cascade downwardly along the sloping wall from heating chamber 1 into reduction chamber 2, becoming intermixed with iron ore and carbonaceous reducing agent supplied by conveyor 13. Rotation of reduction chamber 2 will continuously intermingle the iron ore, carbonaceous material and pellets. The ore and reducing agent are initially mixed with the pellets by being deposited on the sloping wall extending between the main portion of the heating and reduction chambers. After intermixing, the pellets give their heat up to the cooler ore and reducing agent, raising them to a sufficiently high temperature to reduce the iron ore. The temperature need not exceed 1800 F for suitable reduction. The con-

Figure 1



tinuing rotation of reduction chamber 2 will continue to intermix the ore, carbonaceous material and pellets as well as advancing them along the length of the reduction chamber.

When the mass reaches the lower or outlet end of chamber 2, the products remaining will ordinarily be fully or semi-reduced iron and the refractory pellets, although some carbonaceous material may remain. They are separated by passing over screen 17, the reduced iron and any residual carbonaceous material going through the screen. The refractory pellets are gathered in the mouth of passageway 18 and are carried by rotation up the passageway to the head of heating chamber 1. As the pellets pass through passageway 18, they give up their heat to the refractory lining surrounding reduction chamber 2, thereby adding heat for the carrying of the endothermic reduction reaction.

REFINING OF PIG IRON

△ U. S. Patent 2,988,443, issued June 13, 1961 to Paul L. Metz and assigned to ARBED, Acieries Reunies de Burbach-Eich-Dudelange, S.A., provides a method for injecting powdered or granular dephosphorizers from above into a metal bath to be refined.

During all or part of the process an oxidizing gas or an oxidizing gas mixture having the powdered or granular dephosphorizer suspended therein is injected under high pressure or high speed onto or into the metal bath through the inner conduit of the nozzle while an oxidizing gas or an oxidizing gas mixture which contains no dephosphorizer is injected under low pressure or low speed through the outer conduit of the nozzle onto or into the slag floating on the metal.

The process has proved particularly interesting when technically pure oxygen is injected through both conduits.

The dephosphorizer used may advantageously be lime.

The process makes it possible to carry out the refining operation with great flexibility and in particular to control the phenomenon of foaming of the slag and utilize it to advantage in the operation.

OTHER PATENTS OF INTEREST TO THE IRON AND STEEL ENGINEER

Patent No.	Date	Subject	Inventor or assignee
2,985,042	5/23/61	Rolling mill	United Engineering and Foundry Co.
2,985,043	5/23/61	Controlling the screw settings of a reversing mill	United States Steel Corp.
2,985,121	5/23/61	Metallic skewback for furnace roofs	United States Steel Corp.
2,985,277	5/23/61	Apparatus for transferring bulk material	United States Steel Corp.
2,985,400	5/23/61	Strip coiling apparatus	United States Steel Corp.
2,985,440	5/23/61	Pallet construction for sintering machines	Dravo Corp.
2,985,529	5/23/61	Creep-resistant nonaustenitic steels	The Birmingham Small Arms Co., Ltd.
2,986,463	5/30/61	High-strength, heat-resistant alloy steel	Crucible Steel Co. of America
2,986,485	5/30/61	Annealing process for magnetic steel strip	General Electric Co.
2,986,499	5/30/61	Electropolishing steel	E. I. duPont de Nemours & Co.
2,986,784	6/ 6/61	Ladle structure	The River Smelting & Refining Co.
2,986,808	6/ 6/61	Steel body with alloyed zinc coating	Armco Steel Corp.
2,986,992	6/ 6/61	Scrap baling press	Gravity Baler, Inc.
2,987,307	6/ 6/61	Combined continuous sintering and cooler machine	Koppers Co., Inc.
2,987,425	6/ 6/61	Acid pickling process	Imperial Chemical Ind., Ltd.
2,987,429	6/ 6/61	High-carbon razor blade stock	United States Steel Corp.
2,987,787	6/13/61	Stopper rod assemblies	The Joseph Dixon Crucible Co.
2,987,788	6/13/61	Crucible assembly for electric arc furnace	General Electric Co.
2,987,989	6/13/61	Scrap sheet metal balers	Jack L. Freeman
2,988,790	6/20/61	Continuous casting	Schloemann A. G.
2,988,791	6/20/61	Stopper rod assemblies	The Joseph Dixon Crucible Co.
2,988,793	6/20/61	Composite hot top	Oglebay Norton Co.
2,988,803	6/20/61	Feed roller for rolling mills	Heraeus Quarzschmelze G.m.b.H
2,988,966	6/20/61	Surface conditioning of ingots	Guy F. Atkinson Co.
2,989,296	6/20/61	Open hearth steel furnace	E. J. Lavino & Co.
2,989,297	6/20/61	Combined melting hearth and gas reformer apparatus	Inland Steel Co.
2,989,395	6/20/61	Suction draft sintering	Dravo Corp.
2,989,396	6/20/61	Direct reduction of iron oxide by hydrocarbon	Esso Research & Engineering Co.

In particular it has been found advantageous in accordance with the invention to stop the blowing through the outer conduit of the nozzle as soon as foaming has occurred and to continue the operation, blowing only through the inner conduit of the nozzle, with an increasingly larger pressure either by decreasing the distance between the nozzle and the bath, of by increasing the flow of lime and if necessary decreasing the flow of oxygen.

As shown in Figure 2, disposed concentrically about and externally of the inner passageway or conduit 12, is an outer conduit shown in this instance as an annular distribution passage 16, receiving gases through a tube 17 from any suitable source; and discharging them through an annular series of diagonally downwardly and radially outwardly directed openings 18.

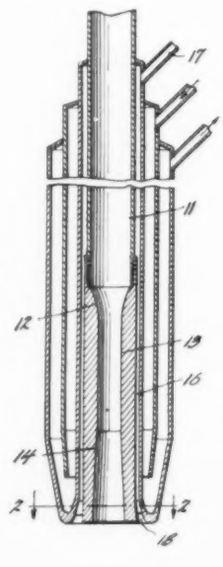
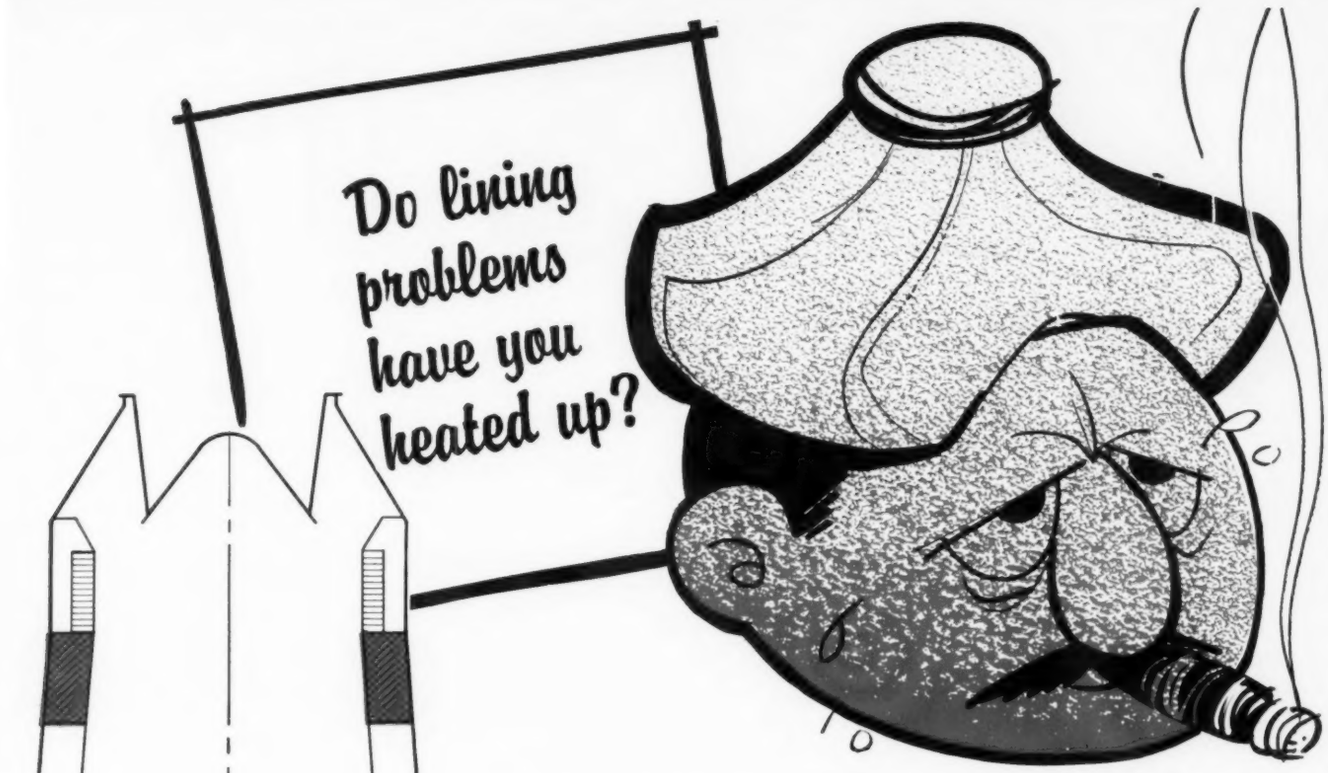


Figure 2

APPARATUS FOR TREATING MOLTEN METAL

△ U.S. Patents 2,988,444 and 2,988,-455, issued June 13, 1961 to Fredrik J. O. Hurum, describe methods for adding substances to a molten bath, which substances tend to float, to vaporize, or to become

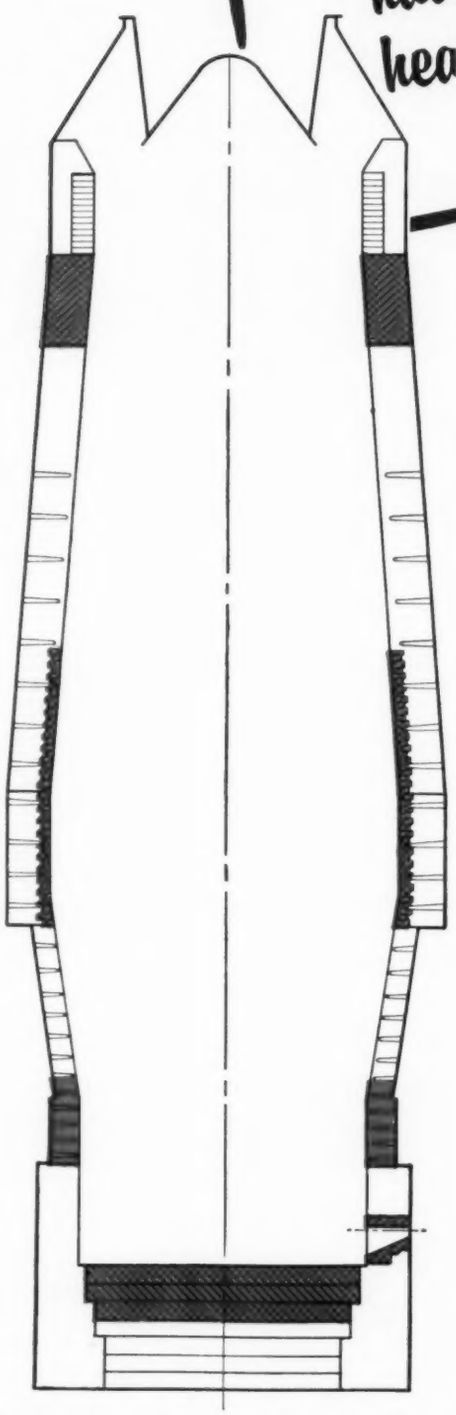


BALANCE BLAST FURNACE LINING LIFE – REINFORCE WITH TAMUL IN CRITICAL AREAS!

The trend toward more severe furnace operating conditions makes TAMUL (Taylor Mullite) the ideal refractory for balancing trouble spots in blast furnace linings. Properties which make TAMUL outstanding are:

- High fusion point
- Outstanding abrasion resistance
- Exceptionally high volume stability
- High long term hot load strength
- Excellent resistance to erosion by metal and slag
- Unaffected by carbon monoxide
- Exceptionally high thermal spalling resistance

Do your blast furnace linings show uneven wear? If so, TAMUL may be the answer to your problem. Write or call for more details.



Typical blast furnace lining showing critical areas (red) that are balanced with TAMUL. For maximum joint protection, TAMUL should be laid up in new, improved TASIL cement.

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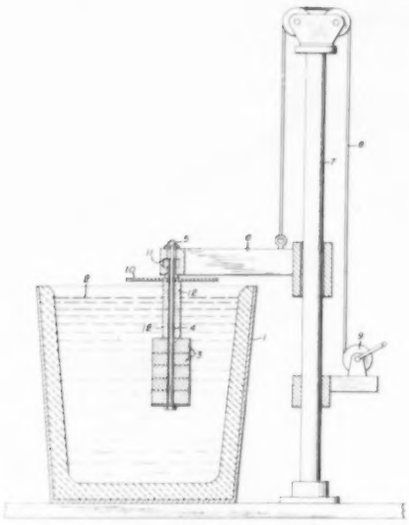


Figure 3

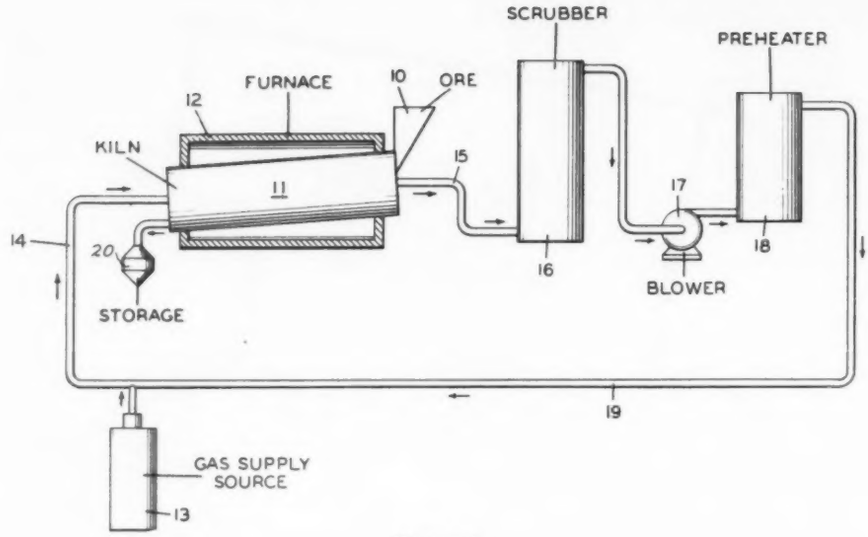


Figure 4

oxidized when brought into contact with the bath.

According to the invention, the substances in question are crushed to suitable grain sizes, and are briquetted. Generally the briquets will attain considerable strength upon drying. By the use of certain plastic bonding agents, the briquets may be hardened at very low temperatures.

As shown in Figure 3, each briquet has an aperture through it and has end surfaces enabling a tight fit of each briquet to adjacent briquets. The briquets are mounted on a rod or wire and are pressed together, so that the briquets will suitably protect the rod or wire against attack from the molten metal when the unit so formed is immersed in the bath of metal.

In this manner it is possible to join briquets of different materials, whereby different reactions are obtainable.

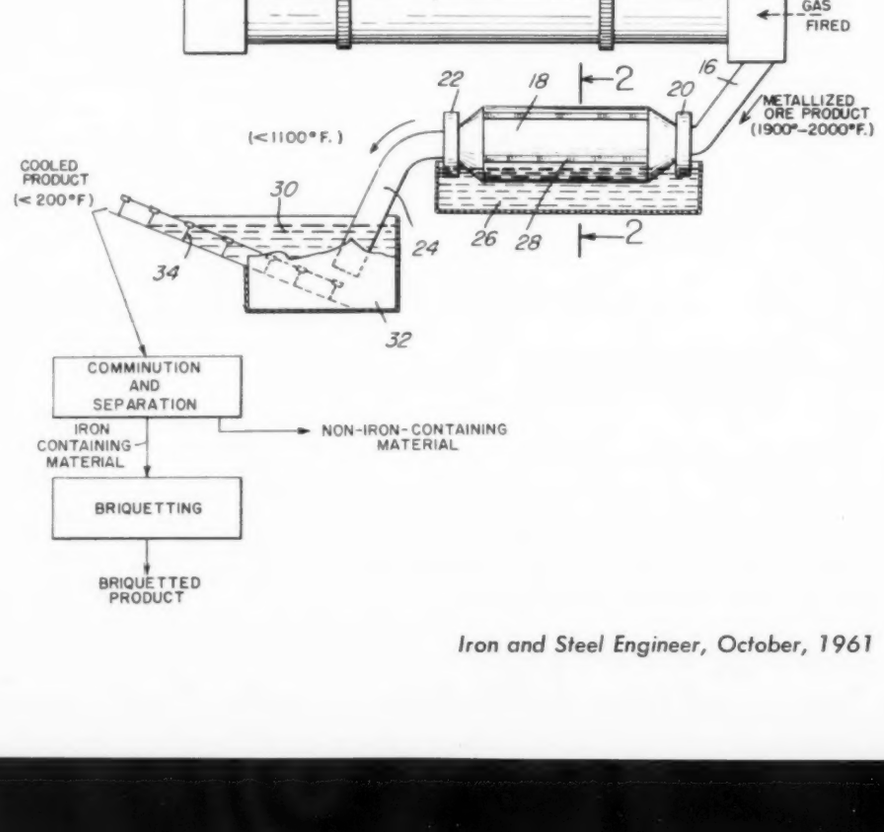
REDUCTION OF IRON ORE BY HYDROCARBONS

△ U. S. Patent 2,988,442, issued June 13, 1961 to Gustaf Tanner, relates to the reduction of iron ores by means of hydrocarbon gases.

As shown in Figure 4, iron ore in a finely divided state is introduced by means of a hopper 10 into an inclined rotary kiln 11. A furnace chamber 12 enclosing the kiln is heated by means of a gas or oil burner or the like to maintain the kiln at a suitable reaction temperature. A hydrocarbon gas, such as for example, natural gas or a mixture of propane and butane is introduced from a storage tank or other source 13 into the left-hand end of the rotary kiln 11 by means of a feed pipe 14 so that the ore travels along the kiln countercurrent to the direction of flow of the hydrocarbon gas. Spent gas is discharged through a conduit 15 at the right-hand end of the kiln into the dust collector and scrubber 16 where the gas is cleaned. Gas is discharged from the scrubber by means of a blower 17 and supplied to a preheater 18 where it is heated prior to return to the conduit 19 for admixture with gas from the fresh gas source 13.

The hot reducing gas supplied to the kiln 11 comes in contact with heated reduced ore containing metallic iron which is a highly effective catalyst for cracking or decomposing the hydrocarbon to deposit carbon in the partially reduced product traveling along the kiln and being discharged into a receiving bin 20. Hydrogen released by cracking of the hydrocarbon flows countercurrent to and in intimate contact with the ore in the kiln and removes between about 40 and 80 per cent of the oxygen from the oxide at the temperature maintained in the rotary kiln 11.

Figure 5



DIRECT REDUCTION OF IRON ORE

△ U. S. Patent 2,986,460, issued May 30, 1961 to Donald E. Babcock, Ralph M. Drews and Sheridan R. Crooks, assigned to R-N Corp., provides a process for direct reduction of iron ore to solid metallic iron.

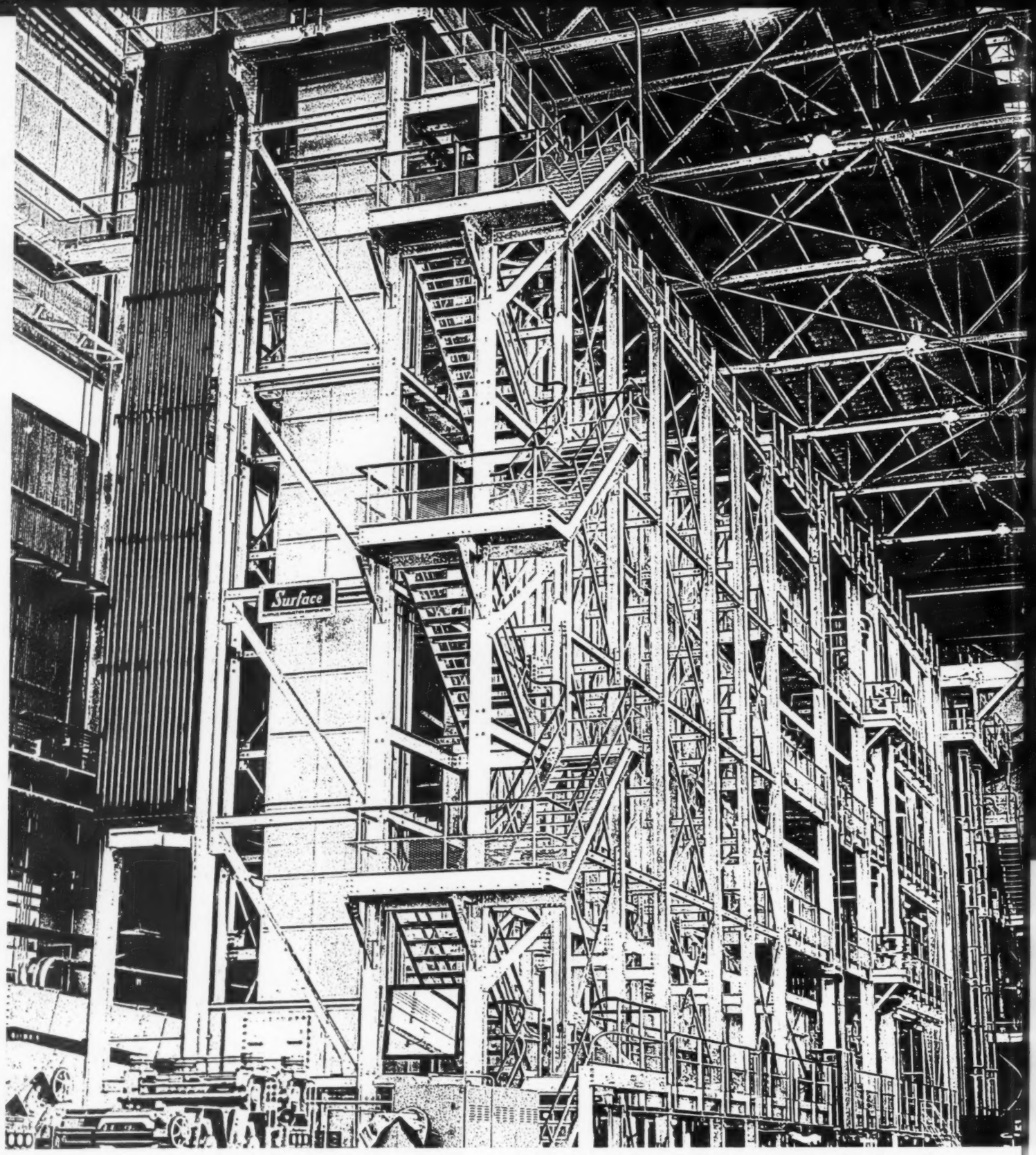
As shown in Figure 5, the reducing operation is conducted in a rotary kiln 10, lined with refractory and thermal insulating material. The feed is introduced continuously through an inlet chamber 12. It advances toward the discharge and combustion chamber 14, while the kiln rotates at an appropriate speed, e.g., about 3 to 5 min per revolution. The kiln is fired countercurrently to the path of the material under treatment, as by appropriate flame directed into the kiln from the combustion chamber, supplied with suitable fuel such as natural gas.

With appropriate control of the kiln operations, a relatively high percentage of the iron oxide in the ore is reduced to metallic iron, the continuous discharge thus representing a highly metallized ore, which also usually includes, however, considerable siliceous or other gangue material and which is usually accompanied by excess coke. The kiln discharge, according to the present invention, travels continuously through a suitably closed chute or conduit 16 to a rotary cooler 18. Here the lumps or other pieces or particles of reduced ore and accompanying material are brought down to a temperature below about 1170 F, by conductive heat exchange through the cooler shell.

The partially cooled material, at a temperature of 1000 to 900 F, is discharged continuously through the outlet conduit 24 which opens beneath the surface of a relatively large body of water 30 in the quench tank 32. The material is withdrawn from the quench tank by suitable mechanical means such as a rake drag indicated at 34.

The cooled product, which contains metallic iron, usually some residual iron oxide, excess coke and other materials, ordinarily including considerable gangue from the ore, is then appropriately processed for ultimate recovery of a final product consisting chiefly of metallic iron.

PACKAGED GAS GENERATORS PACKAGED GAS GENERATORS PACKAGED GAS GENERATORS



Courtesy Columbia-Geneva Steel Division, United States Steel Corporation

Sign of performance better than specified: The modern tin plate industry demands highest quality at lowest operating cost—requirements which can be met only with continuous annealing, a process pioneered by Surface. This Surface installation produces 96,000 lbs/hr of .010″ strip at speeds up to 1500 fpm. Address inquiries to 2404 Dorr Street, Toledo, Ohio.

SURFACE

SURFACE COMBUSTION, Toledo 1, Ohio/ a division of Midland-Ross Corporation MR

BODINE'S SMALL MOTORS OFFER DEPENDABLE SERVICE WITH AN ASSIST FROM NATIONAL BRUSHES

TRADE-MARK

Here, at the Bodine Electric Company Plant, fractional horsepower motors are manufactured for a wide variety of products. Considering the small sizes of the motors used, these products do a tremendous job in making many everyday tasks easier and more enjoyable for the user.

"National" Fractional Horsepower Brushes—tiny but vital components in these motors—offer proved dependability so necessary in this small equipment.

National Carbon Company maintains a complete testing laboratory specifically designed for the investigation of fractional horsepower brush problems. For information, contact your "National" Brush Man or write National Carbon Company, Division of Union Carbide Corporation, 270 Park Ave., N. Y. 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

Contact your "National" Brush Man

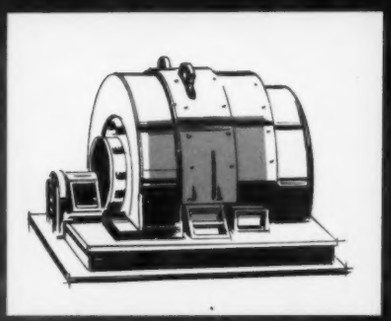
UNION CARBIDE

"National" and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY

STEEL IS ROLLED AT THE HOMESTEAD WORKS WITH AN ASSIST FROM NATIONAL BRUSHES

TRADE-MARK



Rolling mills at the Homestead Works of United States Steel Corporation exert tremendous pressures to squeeze steel into desired thicknesses. The mills are designed to handle terrific mechanical strains ...the motor-generator sets to take the swinging peak loads imposed.

"National" Brushes—wherever they are used on the m. g. sets that power the mammoth mills—provide good commutation and life despite the difficult loading conditions. They contribute to dependable service with minimum commutator maintenance.

To help improve electrical operations, we offer a positive carbon brush service program. Just call your "National" Brush Man or write National Carbon Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N.Y. In Canada: Union Carbide Canada Limited, Toronto.

Contact your "National" Brush Man

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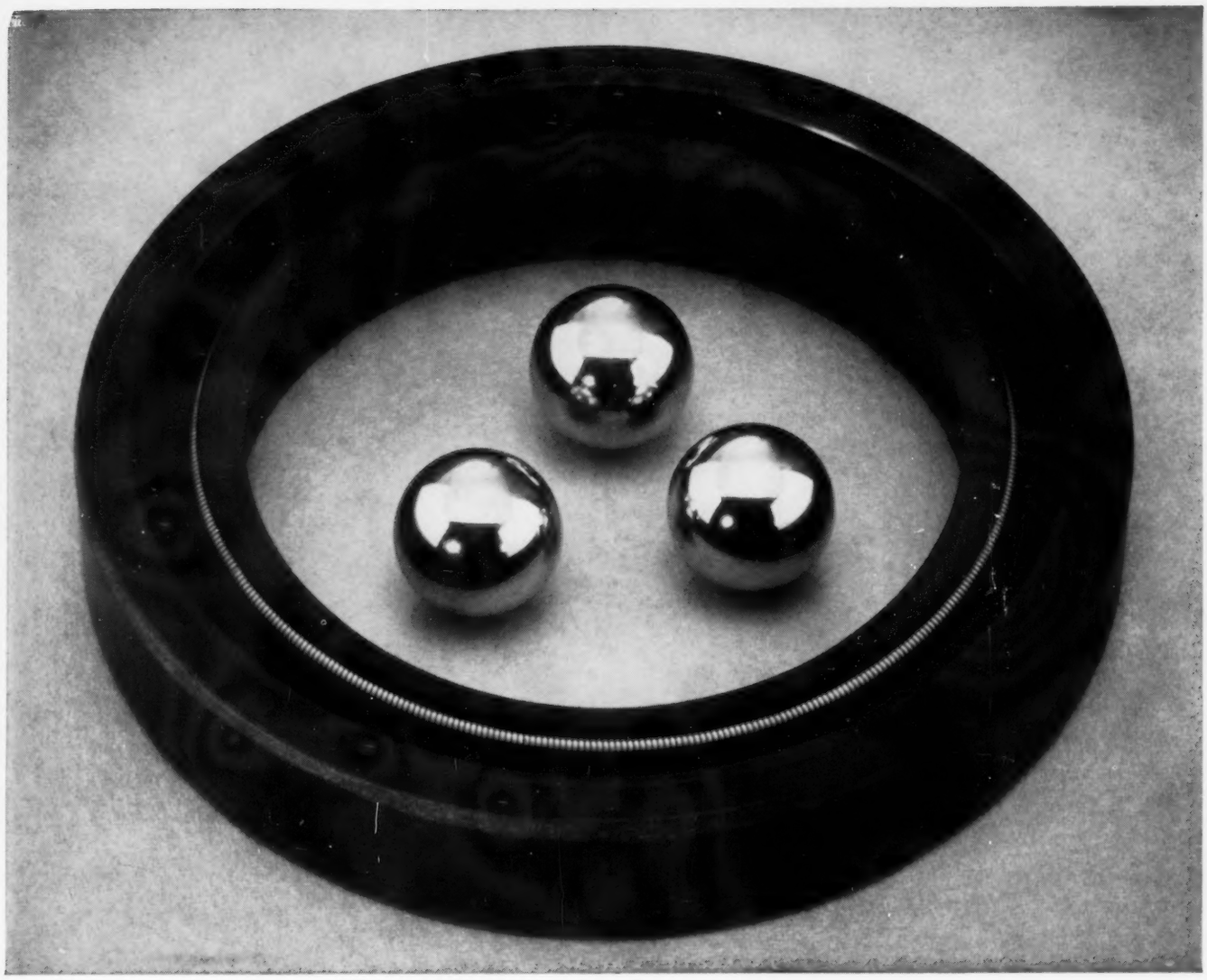


Learn why J-M Clipper® Seals give you better protection for bearings

J-M Clipper Seals protect better because each is specially compounded to do its specific job. When you install the *right* Clipper Seal for your service conditions, it keeps lubricant in, seals out damaging dirt and grit . . . resists heat, speed and corrosive chemicals . . . gives you long, efficient protection. Here are the reasons why you can count on Clipper Seals for better service:

DUAL-COMPOUND CONSTRUCTION. A Clipper Seal consists of a soft, flexible lip and a tough, dense asbestos-compound heel, concentrically molded into one unit. There's nothing in a Clipper Seal that can rust, corrode or cause pitting of bore surfaces. In styles using a garter ring, even the spring is made of stainless steel.

DESIGN. J-M offers many design cross-sections to assure better protection and efficient sealing between regular overhauls.

SPECIAL MATERIALS. J-M will precision-mold Clipper Seals from materials that best suit your requirements. J-M is equipped to work with many materials: elastomers, including Du Pont Teflon . . . neoprene . . . silicones . . . and fluorinated, polyacrylic or other rubbers.

EASY INSTALLATION. Clipper Seals come away clean and easy. Replacement is fast, and requires no special tools or adhesives. You'll never have to scrape or refinish bore surfaces, because the compound heel protects the bore from damage. For quick, temporary replacement, Johns-Manville produces a special split seal.

SELECTION. Your J-M Distributor is a seal specialist. Just tell him your service conditions, and he will help you make exactly the right selection from J-M's wide range of designs, compounds and durometer stocks.

For complete information, see your J-M Distributor. Or write to Johns-Manville, Box 359, New York 16, N. Y. In Canada, address Port Credit, Ont.

JOHNS-MANVILLE
CLIPPER SEALS

JOHNS-MANVILLE JM PRODUCTS

Down go back-up roll costs with

Quality Forged Sleeves

Pictured above is James S. Rennick, a metallurgist with twenty years' experience in the Forgings Division of U. S. Steel. Jim specifies composition, heat treatment, and other processing procedures essential to the production of assemblies as shown in the main picture—a back-up roll that will be used in the cold reduction tin mill at U. S. Steel's Gary, Indiana, plant.

This job points up a curious situation: U. S. Steel is one of the country's leading manufacturers of rolls, and also one of the biggest *users* of rolls . . . a double reason to perfect their performance and reduce their cost . . . just as we did here.

We had to replace a worn, cast steel back-up roll. Rather than replace the entire roll, we machined the face of the roll and shrunk on a *forged* steel sleeve. For back-up rolls like this one, 42" O.D. and larger, this method of sleeving is much less expensive than buying a complete new roll. One arbor can be used for several forged sleeves. A forged sleeve has a hard, wear-resistant surface and is highly resistant to spalling.

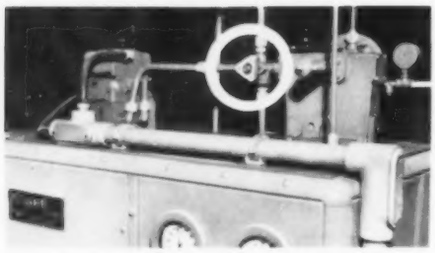
Also, the sleeve is purposely produced with a softer bore to develop a desirable stress pattern, and to provide maximum gripping between the arbor and sleeve after assembly.

There is a good possibility that we can help reduce *your* roll costs. Write or call the United States Steel Office nearest you, or United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

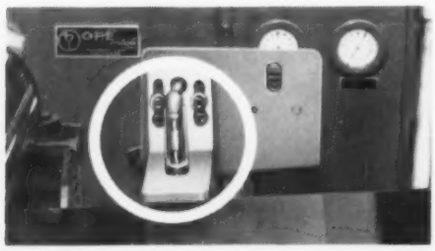
United States Steel Corporation, Pittsburgh • Columbia-Geneva Steel, San Francisco • Tennessee Coal & Iron, Fairfield, Alabama • United States Steel Export Company

United States Steel

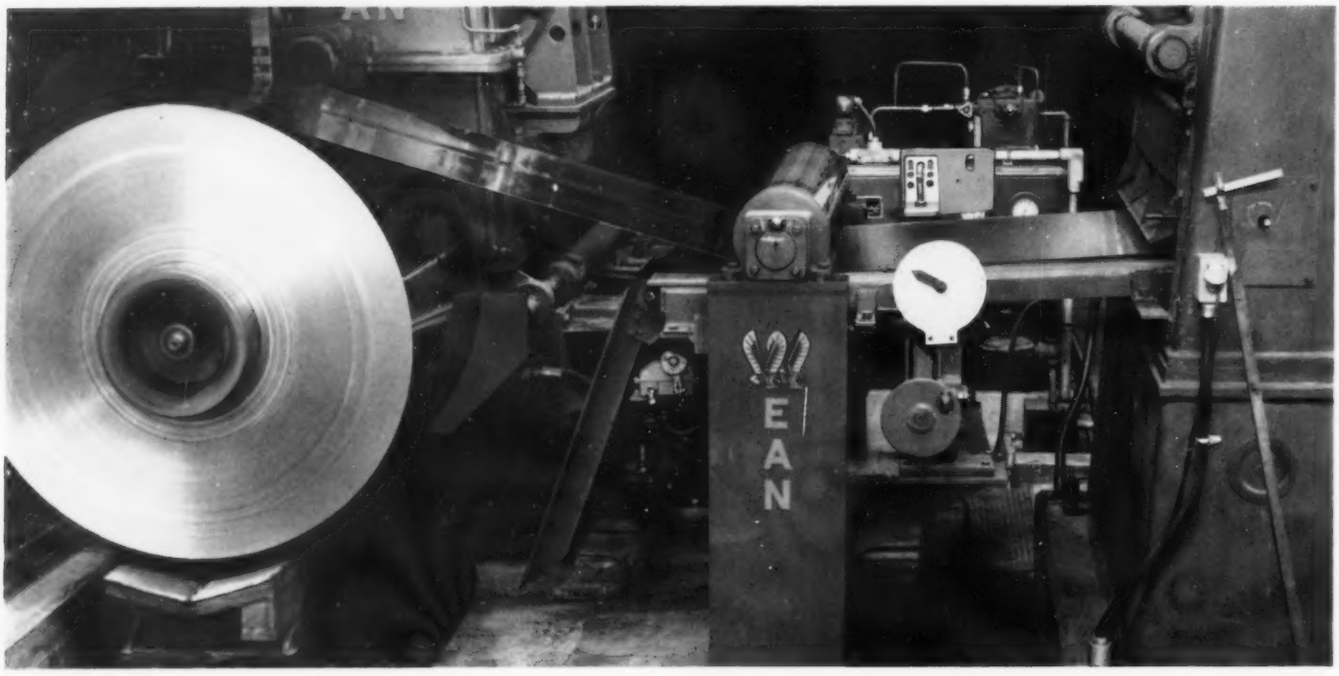
TRADEMARK



GPE CONTROLS ADJUSTABLE-GAIN BOOSTER — Even a slight error in strip position produces maximum corrective force with complete stability. A simple screwdriver adjustment matches the control system to your strip processing line. If it doesn't have this advanced feature, it's just not a modern strip guide!



NON-CONTACT, NON-CLOGGING SENSING HEAD — Nothing touches the gleaming surface of the strip but a breath of air! And only GPE Controls gives you precise, simple pneumatic sensing with patented non-clogging design. Maintains accuracy of control without excessive maintenance.



High-finish tinplate line at Granite City Steel uses GPE Controls Edge Guide for mirror-edge wind-up coil

This GPE Controls air-hydraulic strip guide – on the "B" Electrolytic Tin Line at Granite City Steel – is one of the four similar units now operating in this modern mill. And *three more* GPE Controls Strip Guiding Systems will soon be in operation.

Here at the wind-up, the line operates at about 1000 feet per minute. GPE Controls Strip Guide continuously positions the wind-up reel to produce a mirror-like metal edge on the wind-up coil. Tinplate quality is protected in handling and shipping because the coil edge is perfectly smooth!

Steelmakers and steel users alike have shown their preference for GPE Controls by making it the most widely used strip guide. For simplicity, for control accuracy, for construction that cuts maintenance to the bone–you can't beat GPE Controls!

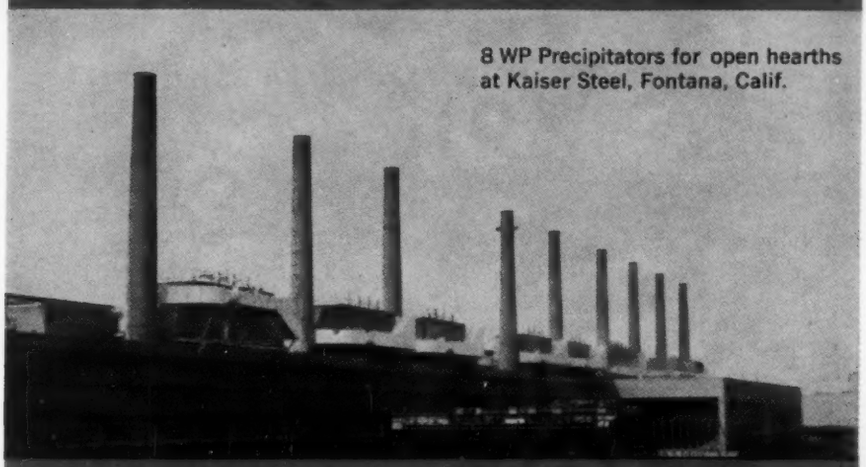
Write for informative Bulletin EG84

GPE Controls, Inc.

240 East Ontario Street • Chicago 11, Illinois.

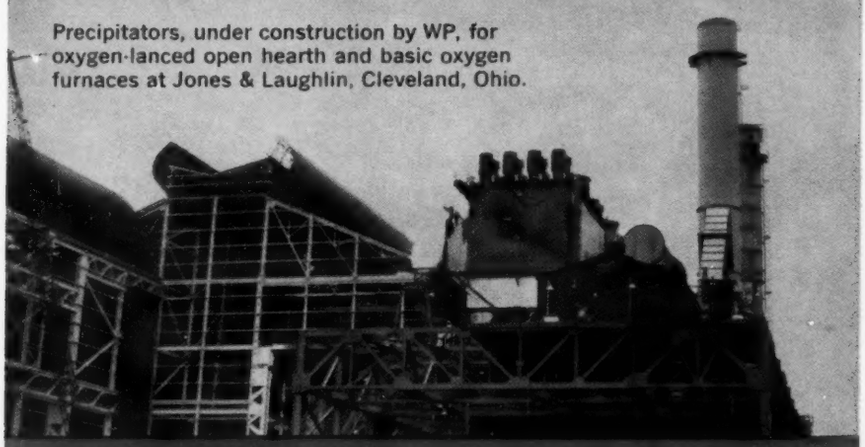
GPE Controls

A Subsidiary of GENERAL PRECISION, Inc.



8 WP Precipitators for open hearths at Kaiser Steel, Fontana, Calif.

Steel plants in California... and Ohio...agree:



Precipitators, under construction by WP, for oxygen-lanced open hearth and basic oxygen furnaces at Jones & Laughlin, Cleveland, Ohio.

When DUST is your problem— CLEAR IT WITH WP*

For an efficient, economical solution to any dust control problem—look to Western Precipitation. WP is uniquely fitted to handle your unique problem—being the one organization that custom designs, engineers and installs ALL types of dust and fume control equipment: Precipitator, Mechanical, Jet-Cleaned Filter, Hi-Temp Filter, Scrubbers and engineered combinations.

With no axes to grind for any one system, WP engineers will give your job a completely unbiased recommendation—whether it's a quote on your specifications, a single component, or a completely engineered installation . . . small, major, simple, or complex.

An inquiry—on your business letterhead—will bring you literature promptly. Just write Western Precipitation, 1000 W. 9th St., Los Angeles 54, Calif. (In Canada, write 8285 Mountain Sights Ave., Montreal, P.Q.)

Dust and fume control since 1907

*WESTERN PRECIPITATION

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Division of Joy Manufacturing Company

ELECTROSTATIC Precipitators
MULTICLONE Collectors
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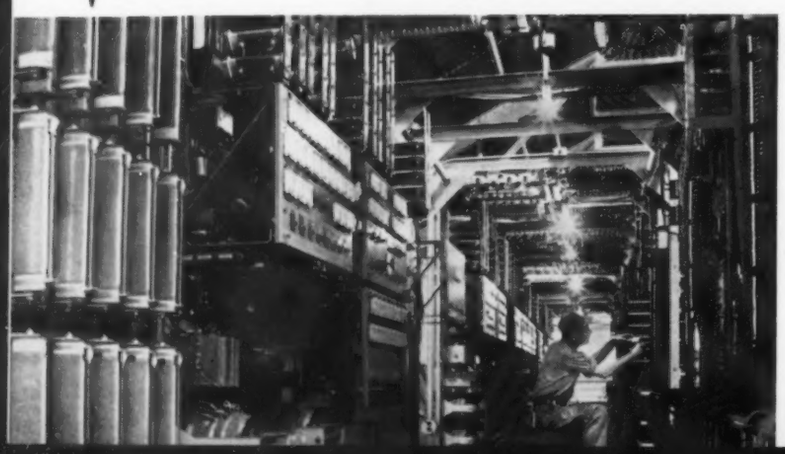
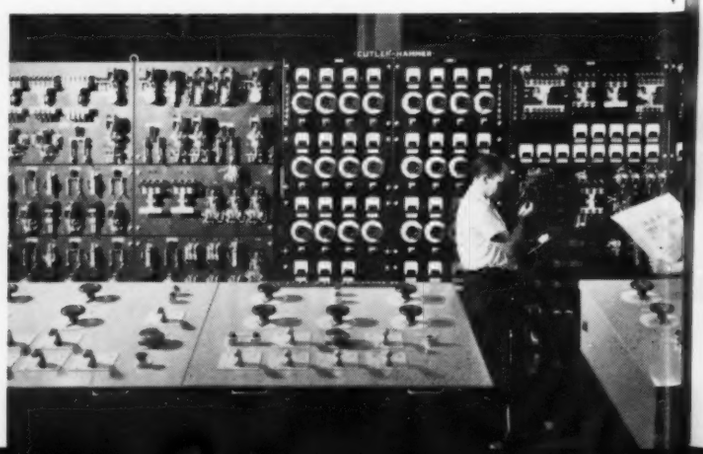
THERM-O-FLEX Hi Temp Filters
TURBULAIRE Scrubbers
JOY-MICRODYNE Scrubbers
also: **HOLO-FLITE** Processors
HI-TURBIANT Heaters
TURBULEX Processers

Call in the C-H man early! Broad experience in all phases of systems control design means the Cutler-Hammer man brings a knowledgeable eye to your particular control problems. Whether your requirements call for a unique solution, as this Granite City job did, or a more standardized system, call Cutler-Hammer.



Cutler-Hammer Test Floor. Here, complete factory tests of systems control prior to shipment insure faster installation, more trouble-free start-ups. Analog computer-simulator can test engineering solutions before construction; simulate response of any motor or machine to aid in actual factory tests.



What's new in systems control?

New Cutler-Hammer synchro tower position control smooths operation of Granite City tinning line

New approach provides stepless tower movement, cuts maintenance required by older systems

Stepless control over the entire range of tower movement is provided for the first time in the steel industry by Cutler-Hammer. In addition, a continuous visual indication of the exact looper position is always available to the operator.

Both entry and exit towers of the tinning line at Granite City Steel Company in St. Louis utilize this new synchro control.

Less Maintenance

Synchro control eliminates the steps, and greatly reduces the amount of maintenance commonly associated with photoelectric tower control systems. Results? Better control, smoother operation of entry and exit sections, which is echoed in better control of the tinning and cleaning section and of the entire line.

The tinning section is where accurate and synchronized speed regulation provided by the systems control engineer contributes to obtaining the ultimate in tin coated strip.

The complex array of continuous process equipment on the Granite City line is driven by 85 D-c motors totalling 1044 hp and is powered by 13 D-c generators. These 98 rotating machines are tied together by a control system which includes 15 static type regulators to insure superior line performance.

Among the reasons for recent Cutler-Hammer achievements in continuous process control is a standard factory pretest procedure, plus an analog computer-simulator that can help engineers test solutions before construction. *You get more benefits when you call in your Cutler-Hammer systems man early in your planning.*

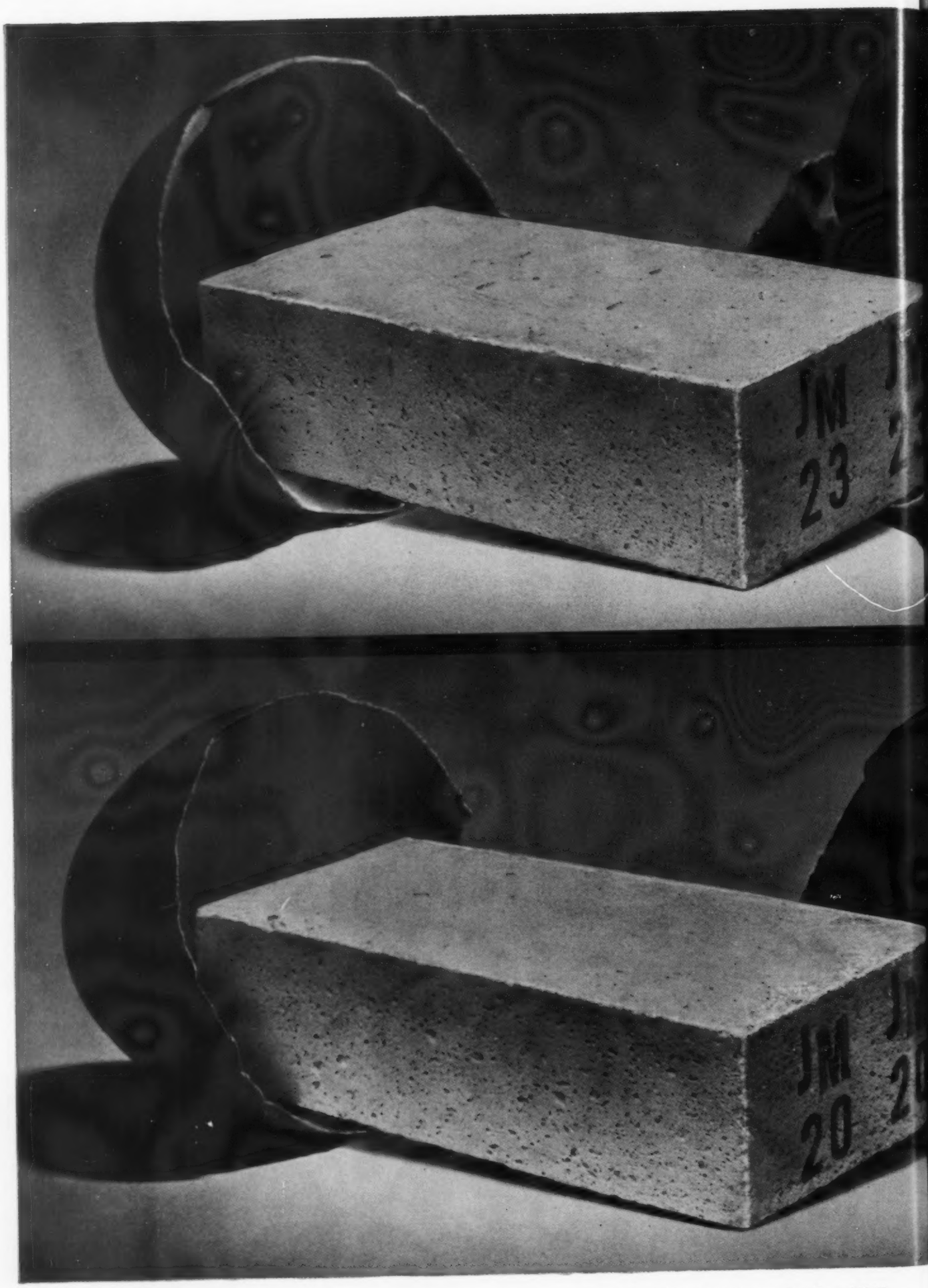
What's new at Cutler-Hammer?

Recent leadership in tinning line control is matched by other Cutler-Hammer systems automation in dozens of continuous process lines. Look for more "firsts" from Cutler-Hammer . . . we've geared up with new production facilities, new engineering talent . . . a *new desire* to help the primary metals industry meet the challenge of the sixties! Call in your Cutler-Hammer man early in your planning.

WHAT'S NEW? ASK...

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wisconsin • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. • Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.


JM
23
JM
20

Just out!
TWO new, high-purity J-M insulating fire brick for use in prepared atmospheres!

Now—just "hatched" by Johns-Manville's Research, Engineering and Production staff—two new, high-purity insulating fire brick: JM-23 designed for service to 2300F and JM-20 for use to 2000F. Both brick are for direct exposure or back-up insulating and are specifically designed to resist such gases as CO, H_2 and CH_4. These brick have the optimum balance of chemical and physical properties for effective heat-control service in prepared atmospheres.

New JM-23 and JM-20 Insulating Fire Brick Provide Outstanding Benefits

- **HIGH PURITY**—The new brick are made from carefully selected materials which have an extremely low iron oxide content.
- **LIGHT WEIGHT**—The new JM-23 weighs substantially less—about ⅓ less—than insulating fire brick previously available in its temperature range. The new JM-20 also is significantly lighter than the brick formerly available in the 2000F range.
- **HIGH STRENGTH**—Both brick have high cold crushing and hot-load strength.
- **HIGH INSULATING VALUE**—Both brick have an extremely low thermal conductivity.
- **SHAPES FROM SLABS READILY AVAILABLE**—Unique production methods perfected by J-M make it possible to cut accurate special shapes from slabs. The slabs are molded, fired rapidly through tunnel kilns and then cut into straights, arches, keys, wedges and a variety of other standard and special shapes.

For Complete Technical Data, Please Fill Out and Return the Coupon Below.

Johns-Manville, Box 14, New York 16, N. Y.
Please send me data on ☐ JM-23 IFB ☐ JM-20 IFB

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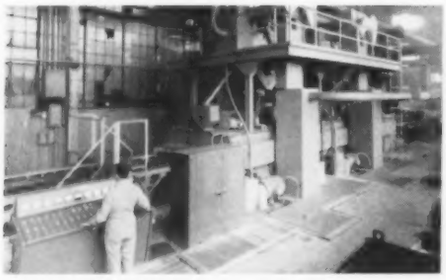
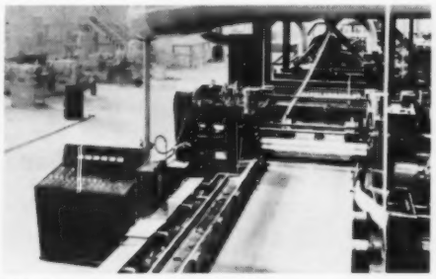
Wheelabrator® cuts descaling and finishing costs 8 ways

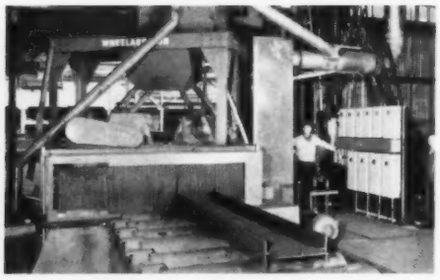
Wheelabrator has built up tremendous technical "know-how" in the descaling of steel since it first pioneered the mechanical descaling process and its associated equipment for the steel industry twenty years ago. This knowledge and experience is reflected in the hundreds of successful cost-cutting applications in eight phases of steel cleaning and finishing. Take advantage of this specialized experience and assistance in developing your modernizing plans. Write today for a copy of Bulletin No. 156-D, "A Pictorial Report on the Modern Concept of Descaling Steel."



Strip and Sheet

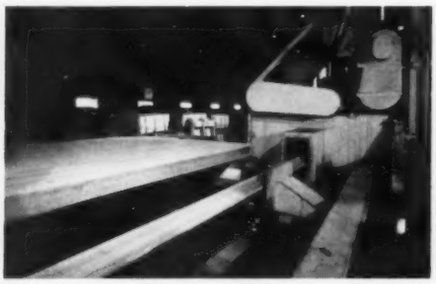


Skelp

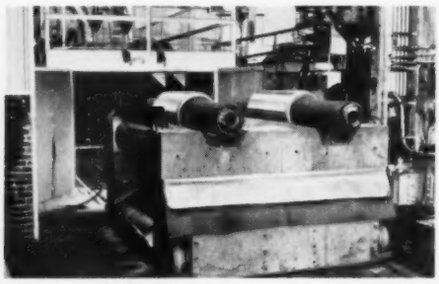


Structural Steel and Plate

Wire Rod and Bar Stock



Inspection of Slabs and Billets



Etching Mill Rolls

A demonstration of WHEELABRATOR'S

VITAL VALUES

VITAL VALUES FOR INDUSTRY

WHEELABRATOR

MECHANICAL DESCALING

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A subsidiary of Bell Intercontinental Corp.

THE IDEAL COUPLER
FOR INDUSTRIAL HAULAGE

SHARON-10A

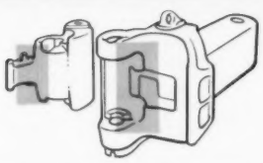
National's Sharon-10A Automatic Couplers are in use throughout the world on industrial cars, mine cars, railroad cars and transit cars. They can be furnished for varying service requirements such as regular top and bottom operation, improved type G side pull, type F side pull, rotary side or rotary bottom operation. For smaller cars not warranting use of the full-size Sharon-10A coupler, they can be furnished in 3/4 size as the Sharon-10 instead of with the full 10A contour.

DESIGN WITH STEEL CASTINGS Centennial 1861-1961 STRENGTH IN SHAPE

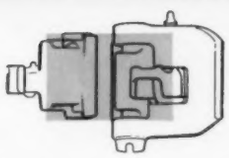
A-1285A

SHARON-10A • SHARON-10A • SHARON-10A

Gives longer service life. Liberal allowance for wear and distortion.



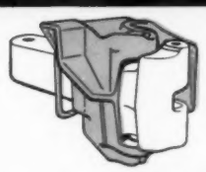
Has greater buffing strength. Substantial buffing shoulders in coupler head and knuckle.



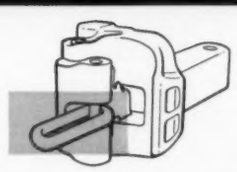
Has less pulling stress. Lugs reduce stresses on knuckle pin.

SHARON-10A • SHARON-10A • SHARON-10A

Features secure locking. V-shaped design stabilizes lock in coupler wall.



Is protected from molten metal. Hood protects uncoupling mechanism from metal splash.



Is versatile. Can be supplied with slotted or off-set knuckle for use with present link and pin equipment.

GEARED TO PROGRESS P R I MEMBER

NATIONAL CASTINGS COMPANY

Established 1868

Transportation Products Division
Cleveland 6, Ohio

International Division Headquarters
Cleveland 6, Ohio

CANADIAN SUBSIDIARY
National Castings Company of Canada, Ltd.
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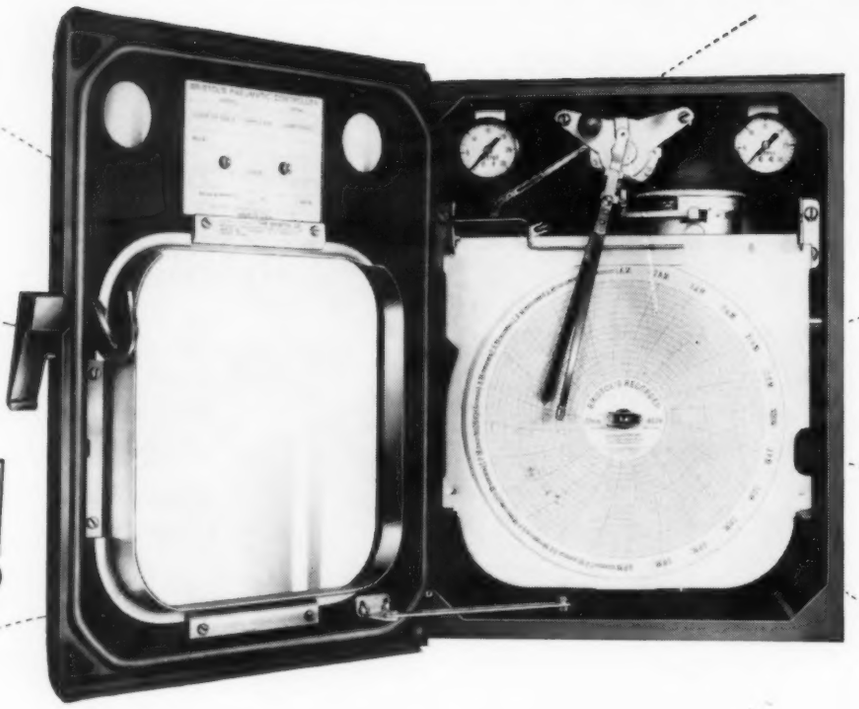
COUPLERS • YOKES • DRAFT GEARS • FREIGHT TRUCKS • JOURNAL BOXES
NATIONAL SPEEDLOADER CONTAINER HANDLING SYSTEM

NEW!



Bristol Series 532 A/D* pneumatic recording controller is outstandingly SIMPLE, RELIABLE, and STABLE

- **Simple modular design for ease of servicing**
- **High control stability for closer process control**
- **Designed for batch-type and continuous processes**
- **Proportional, proportional-plus-reset, and proportional-plus-derivative control models available**

Top control performance with maximum simplicity plus standard Bristol precision measuring elements—those are the key features of the Bristol Series 532 Recording Controller. The 532 uses the same renowned elements that have earned such a reputation for accuracy and dependability on other Bristol automatic controlling and recording instruments—perfected through wide experience and many years of development.

Self-contained modular design of the control unit speeds servicing. The whole modular unit, consisting of an aluminum casting with working parts made of stainless steel, Ni-Span C, and Neoprene diaphragms, can be removed by taking out only two screws and a link.

The die-cast aluminum instrument case (15¾ x 10¾ x 5¾ overall) presents a streamlined appearance and is completely dustproof and weatherproof.

Write for complete data on the new, versatile, economical 532 A/D. The Bristol Company, 123 Bristol Road, Waterbury 20, Conn., a Subsidiary of American Chain & Cable Company, Inc. 0.46

ACCO

CONTROL UNIT CHARACTERISTICS:

PROPORTIONAL BAND: 0-400% continuously adjustable, direct- or reverse-acting.

RESET: 0.1 to 100 repeats per minute.

DERIVATIVE: 0 to 10 minutes derivative time.

AIR PILOT: Non-bleed type.

PILOT CAPACITY: Over 3.0 scfm.

FREQUENCY RESPONSE: Essentially flat to 300 cycles per minute.

TEMPERATURE STABILITY: Less than 0.1% change in the output pressure for 90°F temperature change.

CHART: 8" diameter; wide variety available.

MATERIAL: Aluminum housing; 316 stainless steel internal parts; Ni-Span C feedback element.

RECORDING CONTROLLERS OFFERED FOR:

PRESSURE AND VACUUM: Ranges from full vacuum to 15,000 psi.

TEMPERATURE: Ranges from—100°F to +1000°F.

FLOW AND DIFFERENTIAL PRESSURE: With mercury-type manometer and dry-type differential unit.

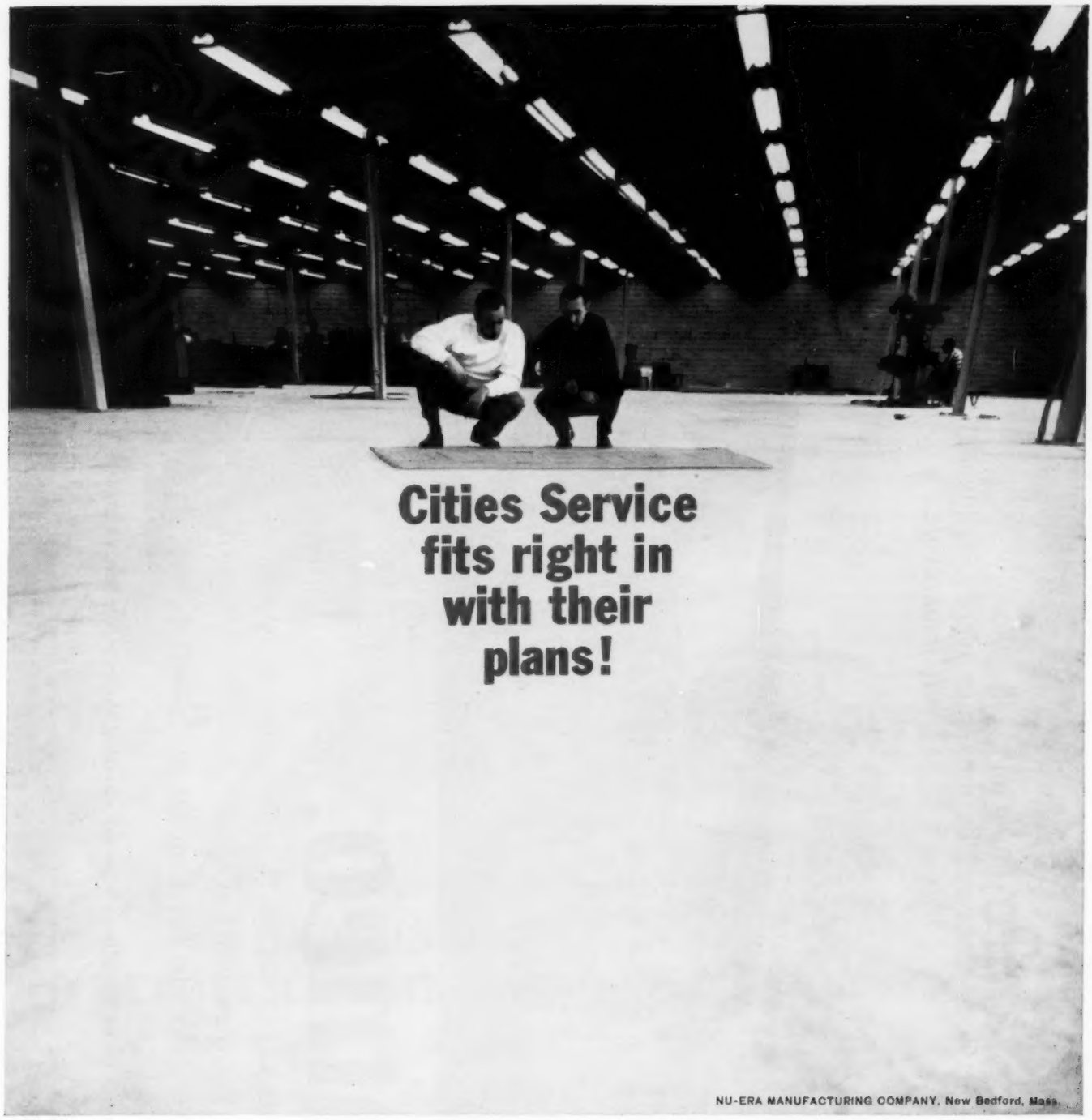
LIQUID LEVEL: With bulb unit and mercury manometer and dry-type differential unit.

HUMIDITY: Zero to 100% relative humidity.

**Advanced Design*

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



Cities Service fits right in with their plans!

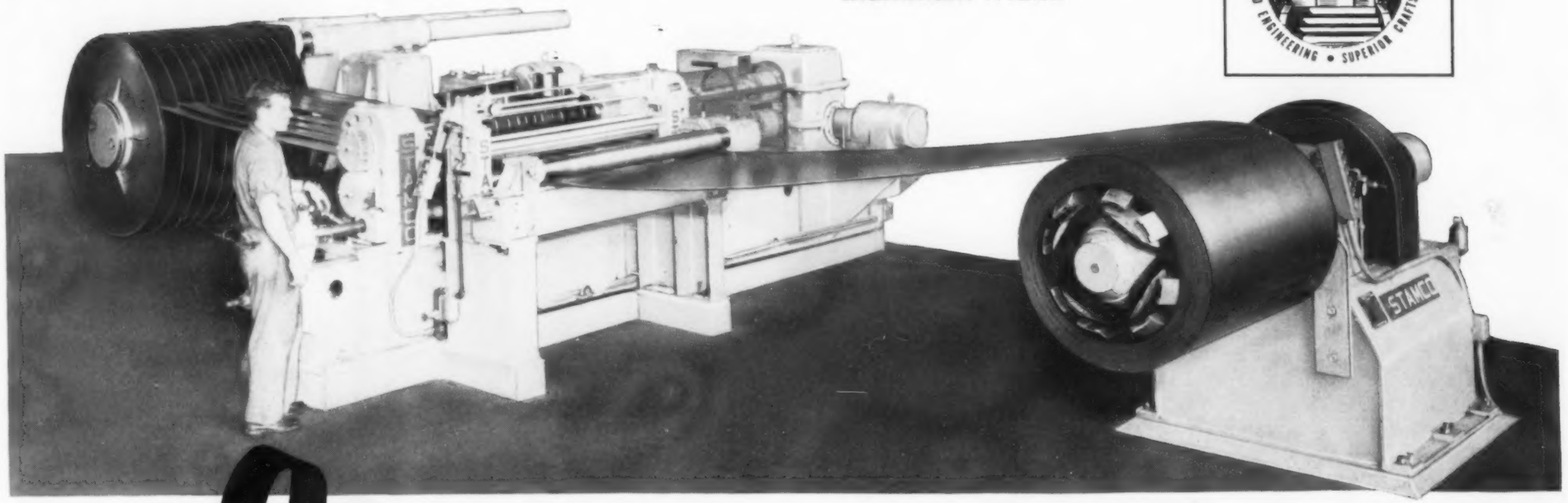
NU-ERA MANUFACTURING COMPANY, New Bedford, Mass.

There's a bright future ahead for Nu-Era, manufacturer of replacement gears. The firm recently built this huge plant to handle increased orders... and Cities Service definitely fits in with their plans. Says General Manager Bill Rebone, "At first, all cutting oil brands seemed to be the same. However, we soon realized that Cities Service oils were giving us superior performance in every respect. Most of our gears are made of #5135 steel, a real tough customer to work with. Yet, we find we're getting long tool life, extra clean cuts with Cities Service Chillo 30 Cutting Oil." Nu-Era now relies, exclusively, on Cities Service for their metal machining fluids. Find out how Cities Service can fit in with your plans. Simply contact your nearest Cities Service office or write: Cities Service Oil Company, 60 Wall Street, N.Y. 5, N.Y.

CITIES SERVICE

Out Front in Quality... Out Front in Service, too!

Stamco *slitting and coiling line for coils of 20 thousand lbs. maximum weight, 52 inches maximum width.*



Stamco, a leader in slitting, coiling and shearing equipment, is in a position to furnish equipment to meet any requirement. Trained sales personnel will gladly consult with you. Write for details to: Stamco, Inc., New Bremen, Ohio, U. S. A.

slitting and coiling lines • cut-to-length lines • flying shear lines • power squaring shears • continuous process lines • ferrous or non-ferrous mill equipment

District Offices, Stamco Sales, Inc.

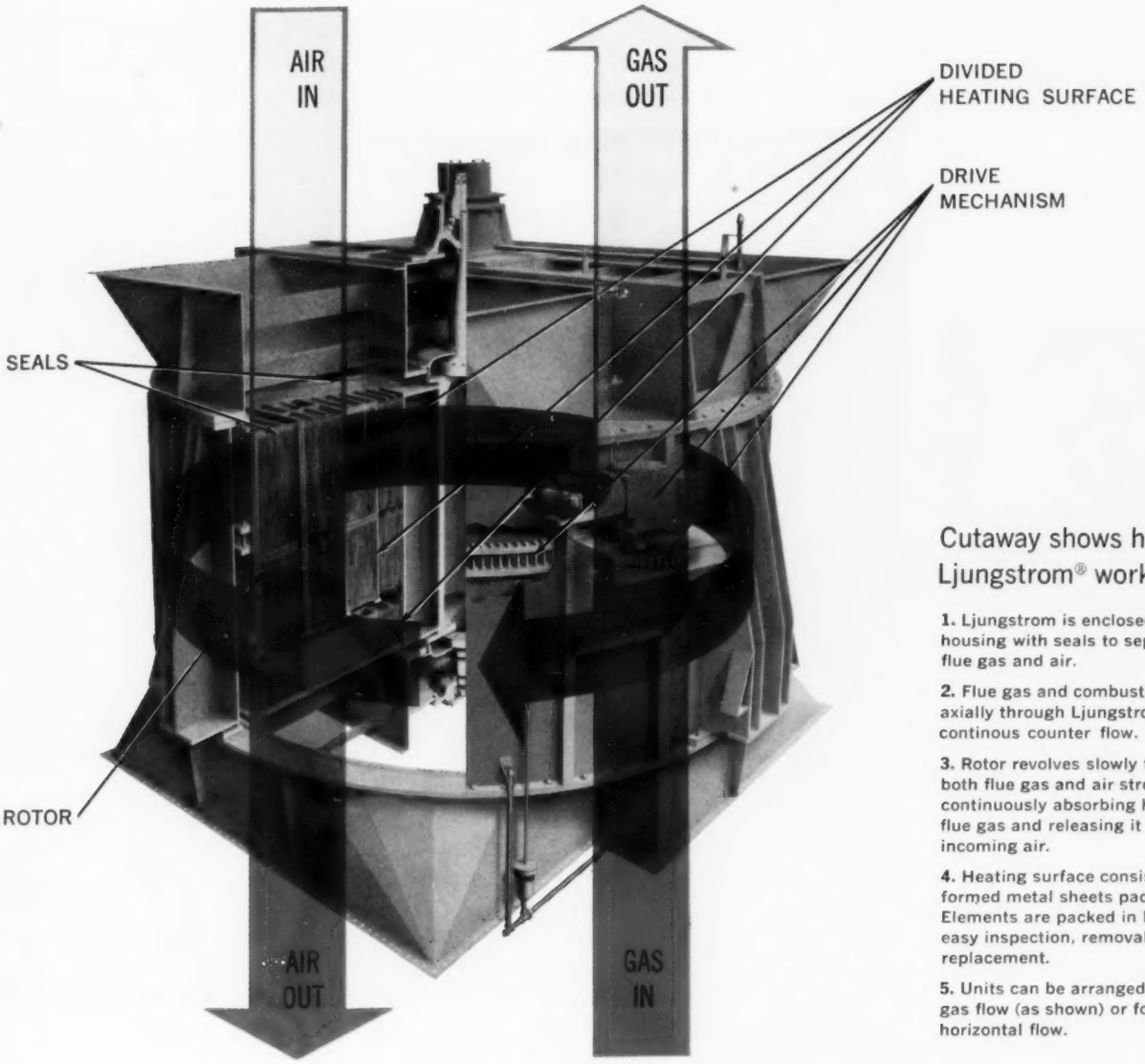
R. P. Popp
18450 Livernois
Detroit 21, Michigan

R. P. Popp
101 Investment Building
Pittsburgh 22, Pa.

I. W. Spraitzar
159 Main Street
Chatham, New Jersey

W. E. Heineman
122 West Burlington Ave.
LaGrange, Illinois

W. H. Millan
11955 Shaker Boulevard
Cleveland 20, Ohio



Cutaway shows how Ljungstrom® works

1. Ljungstrom is enclosed in gas tight housing with seals to separate flue gas and air.

2. Flue gas and combustion air pass axially through Ljungstrom in continous counter flow.

3. Rotor revolves slowly through both flue gas and air stream, continuously absorbing heat from flue gas and releasing it to incoming air.

4. Heating surface consists of many formed metal sheets packed in rotor. Elements are packed in baskets for easy inspection, removal or replacement.

5. Units can be arranged for vertical gas flow (as shown) or for horizontal flow.

HERE IS A WAY TO RECOVER AS MUCH AS 1000°F FROM FLUE GAS

. . . and cut your fuel costs 1% for each 35°-40°F recovered!

More complete combustion . . . higher furnace temperatures . . . increased furnace capacity . . . improved product – these are established advantages of preheating combustion air. And the Ljungstrom® Air Preheater, *on the basis of fuel savings alone,* deserves careful investigation. For it is *the* most efficient metallic heat exchanger ever developed. It can recover as much as 1000°F from flue gas, with savings in fuel costs of 1% for each 35°-40°F recovered.

High efficiency in extremely small space

The Ljungstrom rotor revolves continuously through the flue gas and incoming air . . . absorbs heat and releases it from *the same surface.* Since heat does not have to pass *through* the heat exchange surface, the Ljungstrom is remarkably efficient and compact. A unit measuring 5′ x 7′ x 8′, using 2000°F flue gas diluted to 1500°F, can handle a furnace exhausting 30,000,000 Btu/hr and raise incoming air from 70°F to 1400°F.

Applications in the steel industry

Ljungstroms can perform efficiently in many steel-making applications: reheat furnaces, soaking pits, slab, billet and skelp furnaces. Used in series with checkers they can provide far higher and more uniform preheating than any other heat exchangers now in use.

Tested and proved under all conditions

Ljungstrom's continuous rotary regenerative principle has been performance-proved for more than 35 years in over 3500 units. The electric utility industry (highly conscious of fuel costs) has virtually standardized on Ljungstroms. *Every* major U.S. utility is Ljungstrom equipped, with some units in continuous service since 1923. Refineries, chemical process plants – even ocean liners and cargo vessels – save fuel with Ljungstroms. For more information on how Ljungstroms can benefit you, write:

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N.Y.

Below: A row of Elliott C-W mill motors driving bullet rolls at the delivery end of a billet mill.

"All of these motors are descendents of America's 1st mill-type motor."

From research to reel drives . . .

Elliott C-W Mill Motors serve the st

All along the production lines of America's steel mills, you will find Elliott C-W mill motors driving screwdowns, edgers, run-out tables, shears and coilers. And back of these, Elliott motors furnish power for unloaders, cranes, hoists and other important equipment that moves ore from ships to furnaces.

All this began back in 1904 when Crocker-Wheeler introduced the nation's first mill-type motor. Today, nearly three-score years later, Elliott's newest mill-type motors—the ruggedly-built 620, 622 and 624 frames—incorporate the latest developments in sound, fundamental design. They feature rolled steel frames, split horizontally for easy access . . . glass-bonded Type H insulation . . . low armature inertia for fast speed reversals and reduced operating costs . . . and easy-access, spark-free, excellent commutation.

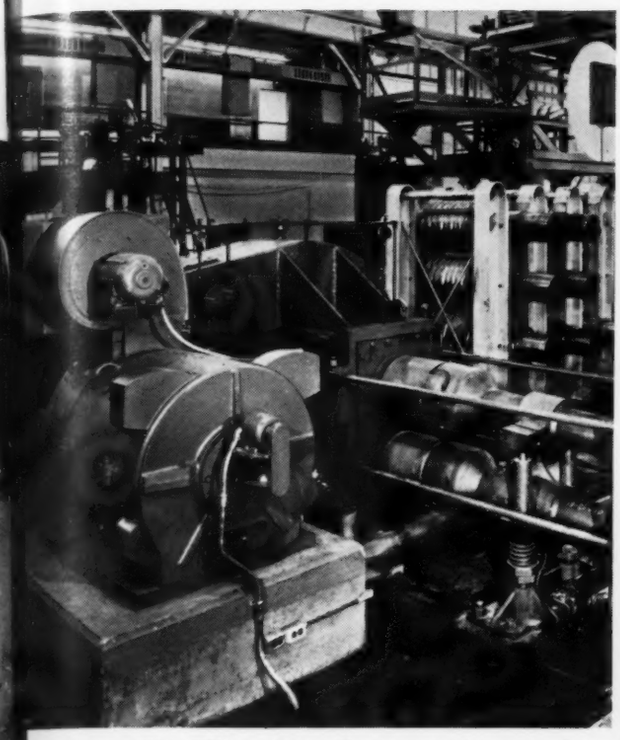
There's much more. Ask for literature which gives complete details.

ELLIOTT COMPANY

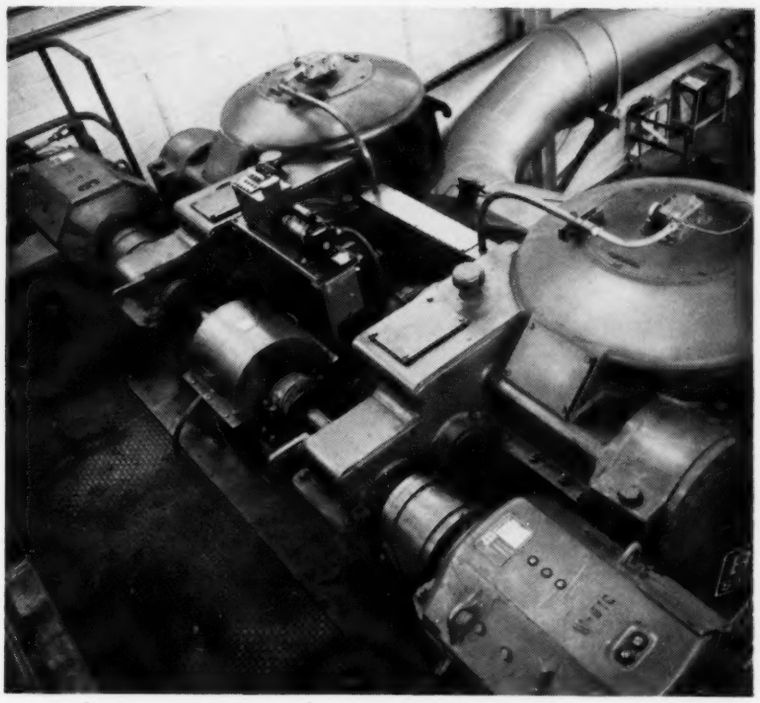
GENERAL OFFICES: JEANNETTE, PENNSYLVANIA

PLANTS: Jeannette and Ridgway, Pa.; Springfield, Ohio

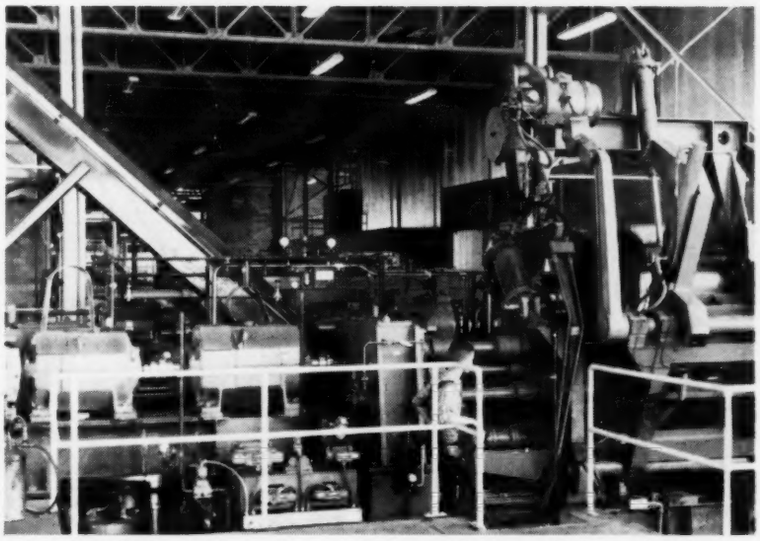
TURBINES • GENERATORS • MOTORS • COMPRESSORS • TURBOCHARGERS • EJECTORS • STRAINERS • TUBE CLEANERS



Above: This Elliott 620 mill motor is the main drive for a reversing hot mill in a research laboratory.

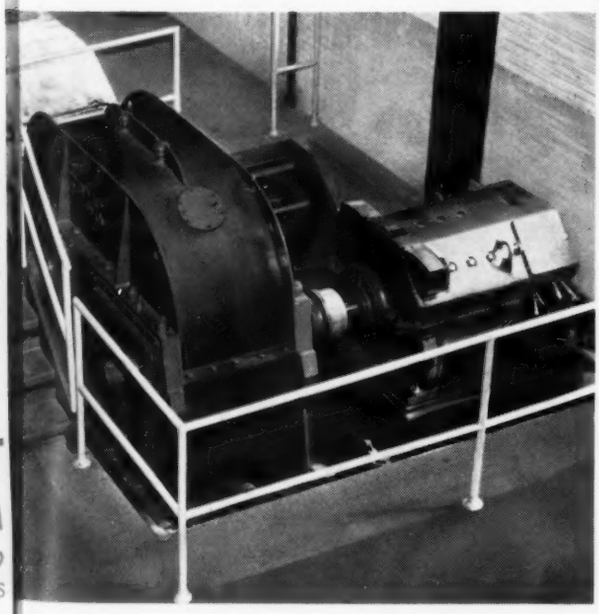


Right: Elliott motors supplying power to drive screw-downs in a reversing cold mill.



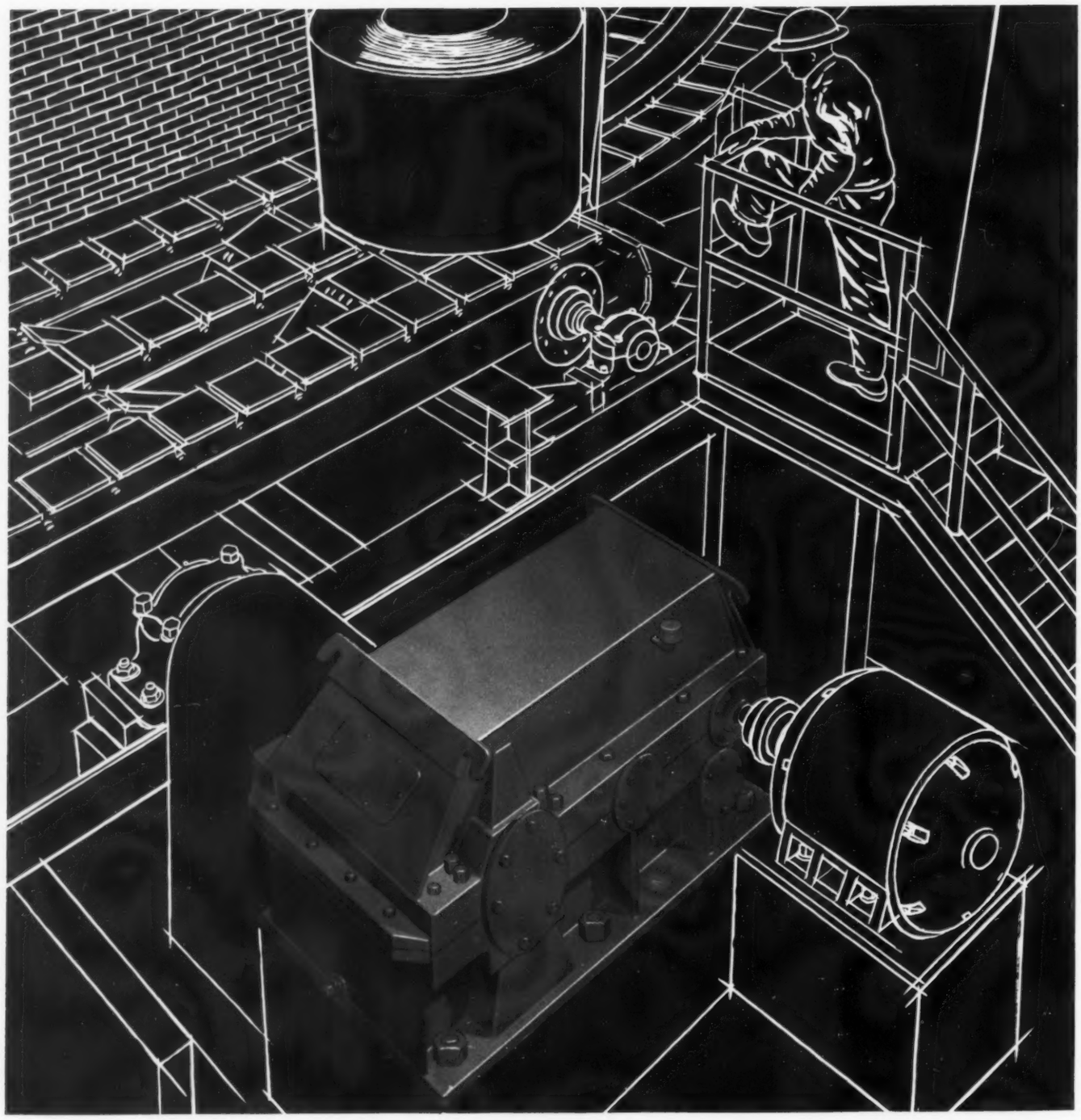
Above: Two Elliott mill motors in tandem driving a slitter and coiler.

steel industry



Left: This Elliott C-W mill motor replaced a steam engine rolling mill drive.

W1-9



LINK-BELT PARALLEL SHAFT MILL DRIVES WITH NEW WELDED STEEL HOUSINGS

shrug off shock loads

Mill engineered Link-Belt parallel shaft drives are built for continuous duty under the most grueling conditions. They are ideal for applications involving heavy shock loads and temporary overloads. The rugged welded steel housings withstand severe external abuse and keep parts accurately and permanently aligned.

Herringbone or double helical gears are arranged in a "balanced" design that provides high-hp, high-ratio reduction. Other features include: positive splash lubrication, high-capacity spherical roller bearings and unique grease-lubricated seals.

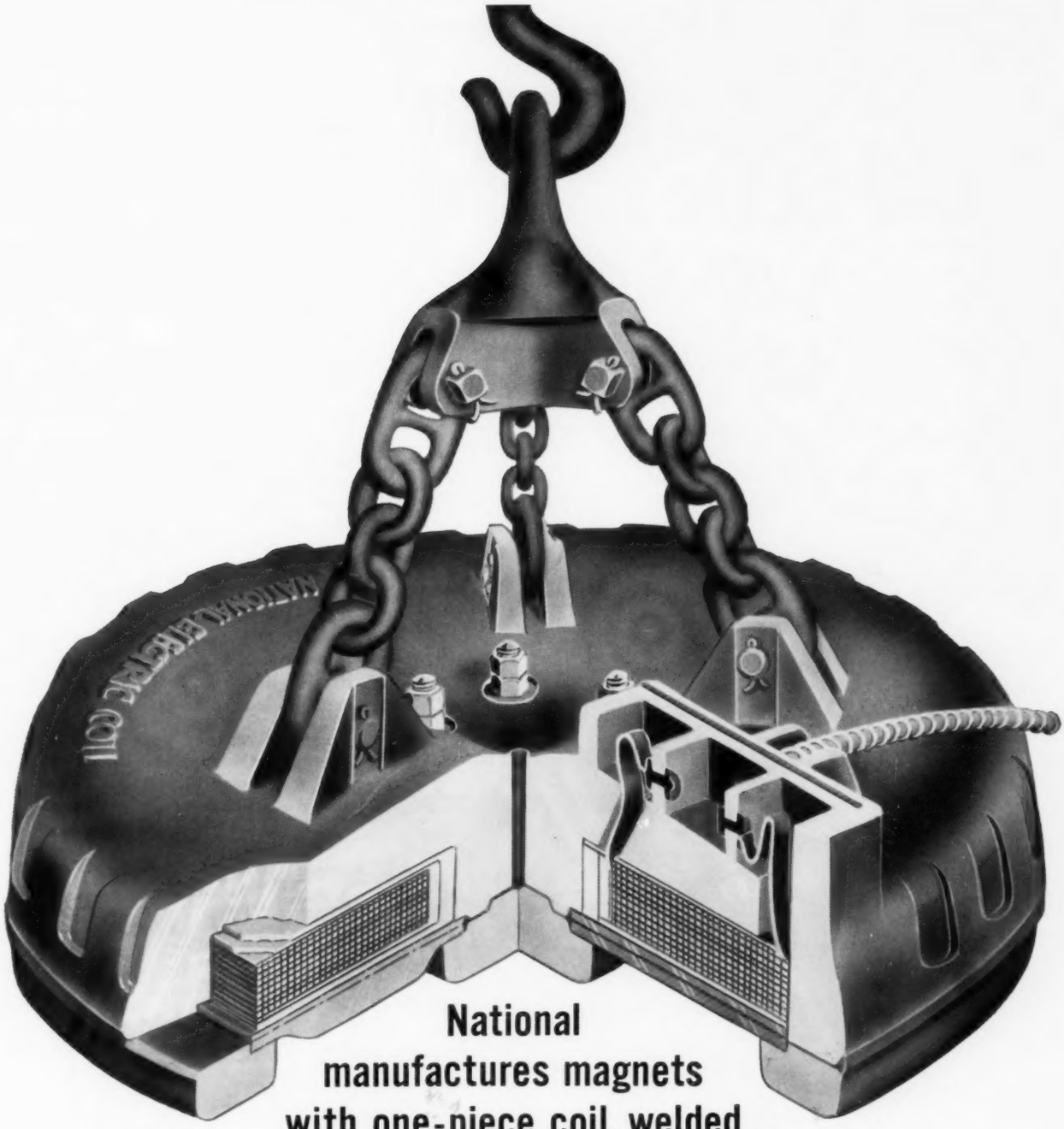
Link-Belt offers 57 sizes . . . shafts projecting at two, three or four locations. Single, double and triple-reduction types, capacities to 2800 hp, ratios to 292:1.

ASK OUR FIELD ENGINEERS for help in solving your application problems. With industry's *most complete* speed reducer line, their recommendations are unrestricted, unbiased. Contact your nearest Link-Belt office or authorized stock-carrying distributor. Ask for Book 2719.

LINK-BELT

SPEED REDUCERS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Warehouses, District Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs; Switzerland, Geneva. Representatives Throughout the World. 15,663



National manufactures magnets with one-piece coil, welded construction for ultimate in service

The coil in this National lifting magnet is wound on a steel spool with square wire insulated with glass fiber, and bonded into a solid mass with Epoxy resin. This feature, plus the use of all-welded construction makes National magnets tops in durability.

These magnets will withstand moisture, severe heat cycling, and mechanical shock.

National's know-how in designing and building magnets is based on years of experience in magnet overhaul and repair. Specify National for long, trouble-free service.

WRITE FOR NEW BOOKLET. Complete information on National's unique magnet design contained in this 8-page booklet. Send coupon for your copy.

National Electric Coil

COLUMBUS 16, OHIO • IN CANADA: ST. JOHNS, QUEBEC

DIVISION OF McGRAW-EDISON

To: NATIONAL ELECTRIC COIL
Division of McGraw-Edison Co.
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Please send free copy of Lifting Magnet booklet

Your name_____

Title_____

Company_____

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Now leading steel producer reports

ALEMITE OIL-MIST WITH THERMO-AIRE® CUTS HOT STRIP MILL LUBRICATION COST 90% ON WORK ROLL BEARINGS!

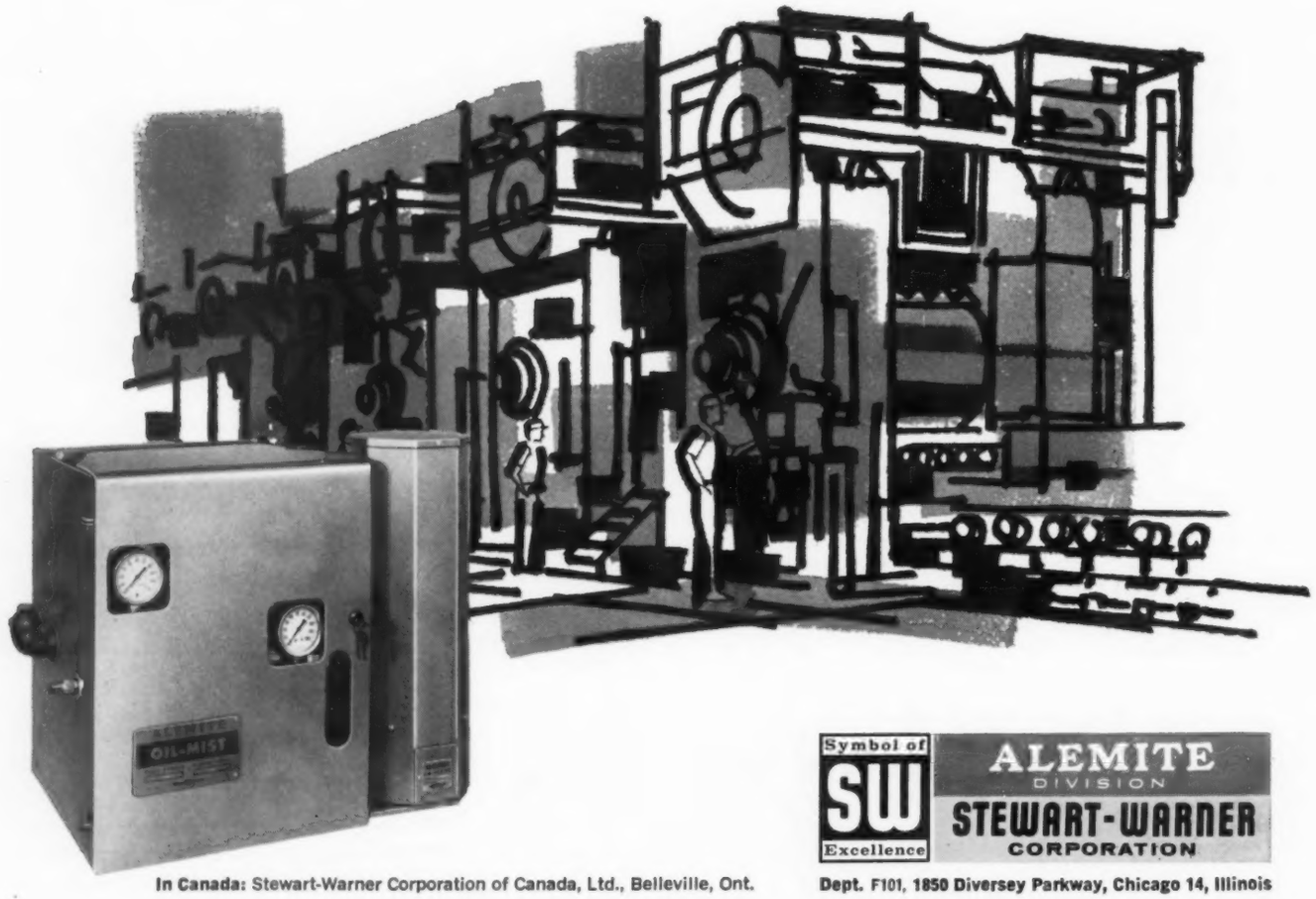
There is no comparison between Alemite Oil-Mist with Thermo-Aire and old-fashioned grease methods!

Take economy. Lubrication savings amount to $32.00 on every turn with Alemite Oil-Mist with Thermo-Aire. Oil-Mist was installed on one stand . . . and is being installed on nine other stands to replace an out-dated system for lubricating 40 roller bearings on an 80-inch hot strip mill. Working 15 turns a week, 52 weeks, these savings will add up to nearly $25,000 a year!

Take efficiency. Alemite Oil-Mist with Thermo-Aire is a fully automatic lubrication system. It applies lubricants constantly, properly, *without losing a minute of valuable production time.* It eliminates expensive packing of bearings with grease and also completely eliminates need to clean bearings of old grease. Its exclusive "Thermo-Aire" feature preheats incoming air—permits atomization of even the heaviest straight mineral oils to supply heavy-duty bearings with the high viscosity lubricants they need for smooth, steady performance.

Alemite Oil-Mist with Thermo-Aire will improve mill operating efficiency... lengthen bearing life . . . cut oil consumption and prevent product spoilage.

Write for illustrated brochure form 37-32, or see your Alemite representative for the amazing story of Alemite Oil-Mist with Thermo-Aire and how you can benefit from it!



Symbol of SW Excellence

ALEMITE DIVISION
STEWART-WARNER CORPORATION

In Canada: Stewart-Warner Corporation of Canada, Ltd., Belleville, Ont.

Dept. F101, **1850 Diversey Parkway, Chicago 14, Illinois**

REX®

helps a giant keep a "mile-a-minute" pace

Rex Coil Conveyor Chain used at Cuyahoga Works, American Steel and Wire Division, United States Steel Corporation

Rex Rod Coil Conveyor Chains were selected by Morgan Construction Company of Worcester, Mass., to help this giant four strand "rod mill of the century" keep a mile-a-minute production pace on the lines shown here.

The job: carrying steel rod coils, up to 1000 pounds, down two production lines, each having two conveyor groups...one group 330 feet long; the other, 252 feet long.

Specifications required chain with a carefully balanced combination of strength, wear life and economy. Rex Engineers, with 70 years of chain design, manufacturing and application experience coupled with modern research and quality control, delivered the goods! Rugged Rex 3557 Coil Conveyor Chain, shown at work above, was the answer.

Why not ask Rex Engineers to help you with planning and replacement problems.

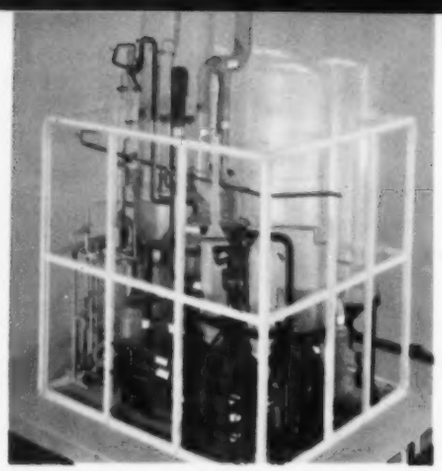
Write CHAIN Belt Company, 4693 W. Greenfield Ave., Milwaukee 1, Wis. In Canada: Rex Chainbelt (Canada) Ltd., Toronto and Montreal.

REX®

CHAIN BELT COMPANY

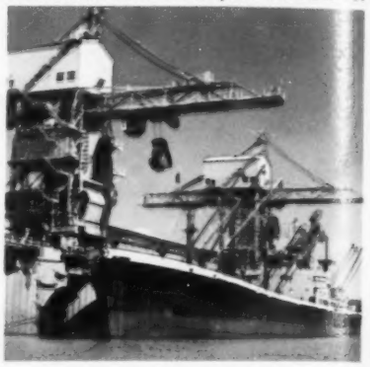
ILLINOIS: This Dravo-Lurgi sinter plant has rated capacity of 3900 tons per day. Over 45% of new U.S. sinter capacity added by steel industry in past five years are Dravo-Lurgi plants. A second Dravo-Lurgi pelletizing plant is being added for a large metal-producing company. Mail coupon for information on sintering, pelletizing, briquetting, beneficiation or other ore processing services.

MINNESOTA: Taconite shipping facility—2,334-foot dock, harbor and breakwater — built by Dravo on Lake Superior.



MICHIGAN: Engineering model of the cold box for 280-ton-per-day oxygen plant, now under construction for steel division of a major auto maker, will be first low pressure plant in U.S. to produce simultaneously gaseous and liquid oxygen without high pressure cycle. Dravo designs and builds air and gas separation plants under arrangement with Linde AG of Munich, Germany. Dravo turn-key services also include power and steam plants, water pumping and treatment stations, other plant utilities. Send the coupon for data.

LOUISIANA: Dravo-built twin n-loaders and dock handle variety of materials at versatile ship/ba ge facility on Lower Mississippi. R g-ged, efficient materials hand ng equipment can reduce costs of n-loading ore, coal, other bulk c m-modities and containerized ca go for water-side plants and port n-stallations. Send coupon for deta s.



PENNSYLVANIA: Dravo *Tru-weld* grating is produced by modern, highly automated equipment. It is used on all types of applications where open steel flooring and stairs are needed; is available direct or from distributors throughout U.S., in standard panels or fabricated. Check coupon for information.

NEW YORK: New forced air, stationary cooler, new sinter breaker, hot screening facilities and other plant modifications helped major steel producer improve sinter quality and production. Similar programs are underway for two other existing plants. Check coupon for information on stationary, induced-draft circular or straight-line coolers, breakers, screens or sinter plant modernization services.

Harbor in
Minnesota

Sinter Plant in
Illinois

Oxygen Plant in
Michigan

Unloaders & Dock in
Louisiana

Grating in
Pennsylvania

Process Modernization in
New York

Dravo Corporation, 4770 Grand Avenue, Pittsburgh 25, Pa

Please send me information on the following products and services

- ☐ Docks, Harbors, Foundations
- ☐ Water & Waste Treatment
- ☐ Ore & Coal Unloaders
- ☐ Sinter Plants & Coolers
- ☐ Pelletizing & Briquetting
- ☐ Oxygen Steelmaking
- ☐ Ore Beneficiation
- ☐ Oxygen Plants
- ☐ Mill Lubrication
- ☐ Turbo Blowers
- ☐ Space Heaters
- ☐ Ore Bridges
- ☐ Towboats & Barges
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- ☐ Steam Plants
- ☐ Fabricated Piping
- ☐ Grating

Name_____ Title_____

Company_____

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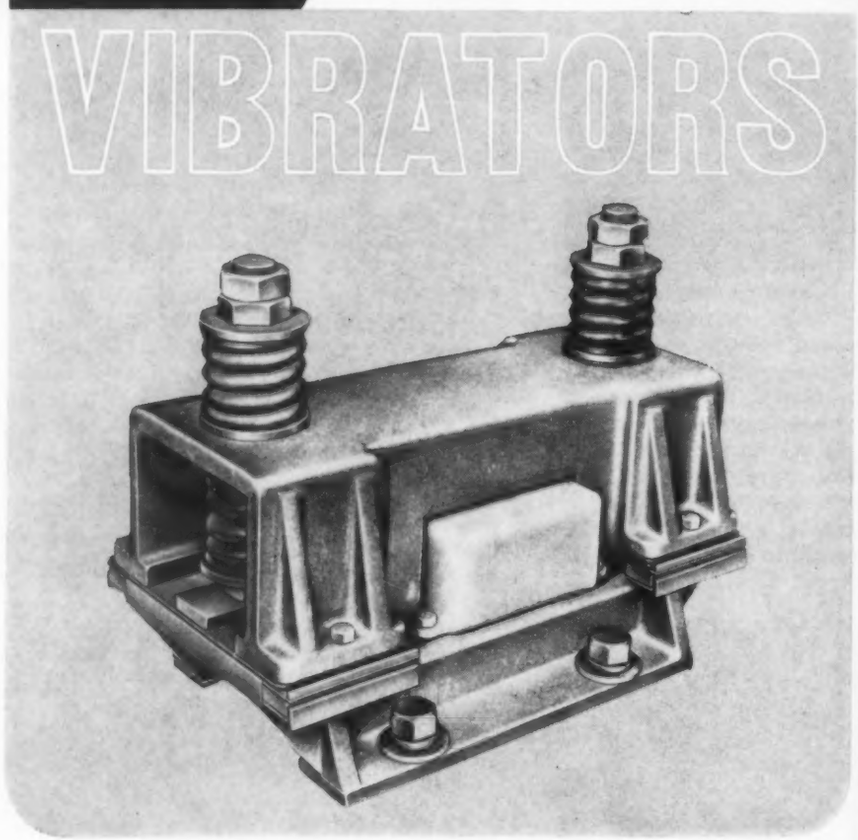
City_____ Zone_____ State_____

DRAVO

KEEP BULK MATERIALS FLOWING FREELY

SYNTRON ELECTRIC VIBRATORS



ASSURE STEADY MATERIALS FLOW FROM BINS, HOPPERS, CHUTES

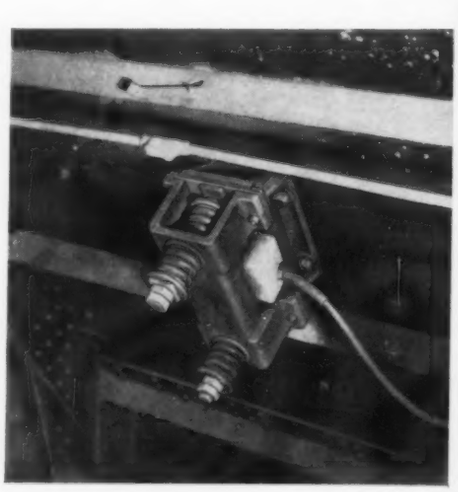
Syntron builds an Electromagnetic Bin Vibrator unit to meet almost every requirement. Prevents most types of bulk materials from arching or plugging in bins, hoppers, and chutes.

The Electromagnetic drive unit produces 3600 instantly controllable vibrations per minute, providing a steady materials flow to processing equipment.

Every Syntron Electromagnetic Bin Vibrator is rugged and durable. The absence of mechanical moving parts assures long, trouble-free service with very little maintenance.

Keep bulk materials flowing efficiently and economically.

Write for a Syntron Catalog and the name of the representative nearest you.



Write for a Syntron Catalog and the name of the representative nearest you.

61V2

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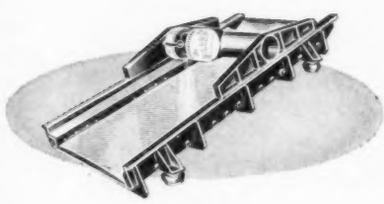
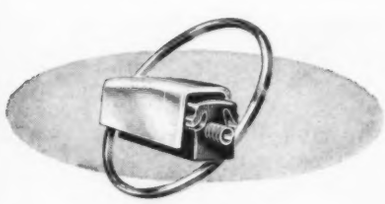
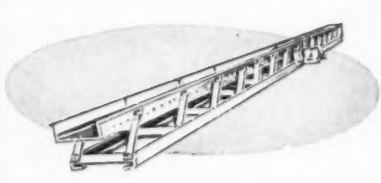
Other SYNTRON equipment of proven dependable quality



Vibrating Screens



Roll Neck Seals



Mechanical Vibrating Conveyors

Car Shakers

Lapping Machines

SYNTRON COMPANY
699 Lexington Avenue • Homer City, Pa.

You cannot afford to ignore the New Allen-Bradley BULLETIN 709 Starter Line

SIZE 00
1½ HP, 220 V
2 HP, 440-550 V

SIZE 0
3 HP, 220 V
5 HP, 440-550 V

SIZE 1
7½ HP, 220 V
10 HP, 440-550 V

SIZE 2
15 HP, 220 V
25 HP, 440-550 V

SIZE 3
30 HP, 220 V
50 HP, 440-550 V

SIZE 4
50 HP, 220 V
100 HP, 440-550 V

SIZE 5
100 HP, 220 V
200 HP, 440-550 V

They OUTPERFORM and OUTLAST ALL Others

These new Allen-Bradley starters bring you the greatest advance in reliability and life in all motor control history. Also, they possess a compactness that's almost unbelievable—especially in the higher ratings.

The new Bulletin 709 solenoid starters feature a patented, high-efficiency magnet, which is cushioned to reduce shock and wear. Contacts are of weld-resistant cadmium oxide silver. All coils are "pressure molded" for protection against physical damage and destructive atmospheres. The two or three solderpot overload relays are trip-free and tamperproof. Brooks Stevens, famous industrial designer, has given the new enclosures a styling that adds "eye appeal" to every installation. To get full details, contained in Publication 6100, please write today to: Allen-Bradley Co., 1316 S. Second Street, Milwaukee 4, Wisconsin.

SIZE 00 NOW AVAILABLE

Provides the same long life and reliability as others in the Bulletin 709 family. Rated 1½ HP, 220 V; 2 HP, 440-550 V.

15-G1-MR

ALLEN-BRADLEY

Member of NEMA

QUALITY MOTOR CONTROL

Here Your Motor Starter Dollar Buys

MORE OF THE QUALITIES YOU NEED

BULLETIN 709 SIZE 3
across-the-line solenoid starter in Nema Type 1 enclosure.

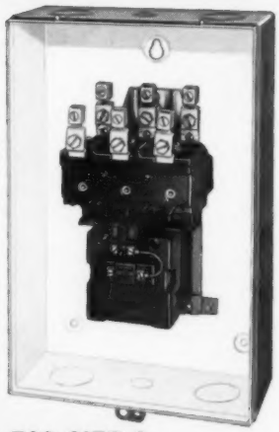
Where else could you possibly obtain—in one complete line—all of the desirable features of the ideal motor control...

1. **Smaller size**
2. **Greater reliability**
3. **Remarkable switching capacity**
4. **Longer life**
5. **Conscientious overload protection**
6. **Simpler installation**
7. **Complete accessibility**
8. **Beautiful appearance—either open or enclosed**
9. **Surprising light weight**

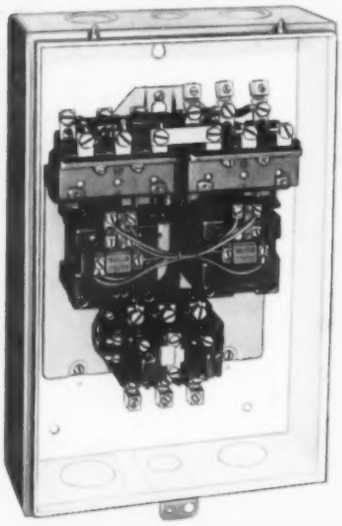
The heart of this new line of magnetic motor starters is the unique solenoid contactor. While it retains the famous A-B one-moving-part principle, it is completely new and far more efficient. This fact is reflected in reduced dimensions for all of these controls. Yet, this contactor design will perform reliably for many more *millions* of trouble free operations.

The new enclosures are very "eye appealing." When the open type starters are assembled into special panels, their neatness and compactness will delight the designers. Full details are in Publication 6100. Please write: Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.

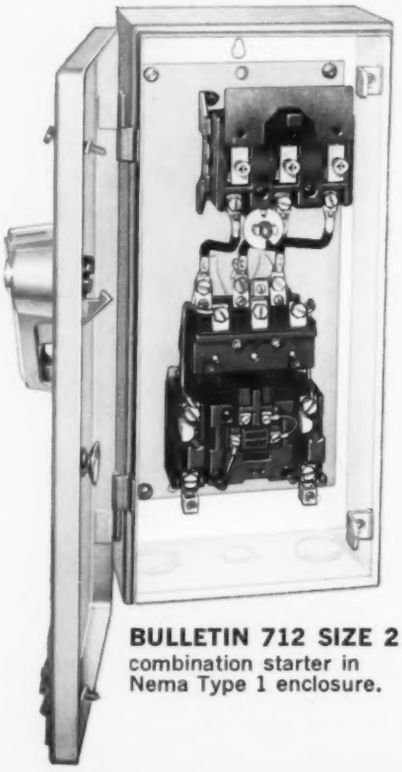
A-B QUALITY



BULLETIN 702 SIZE 3
three-pole, a-c solenoid contactor in Nema Type 1 enclosure.



BULLETIN 705 SIZE 2
across-the-line reversing starter and overload relays in Nema Type 1 enclosure.



BULLETIN 712 SIZE 2
combination starter in Nema Type 1 enclosure.

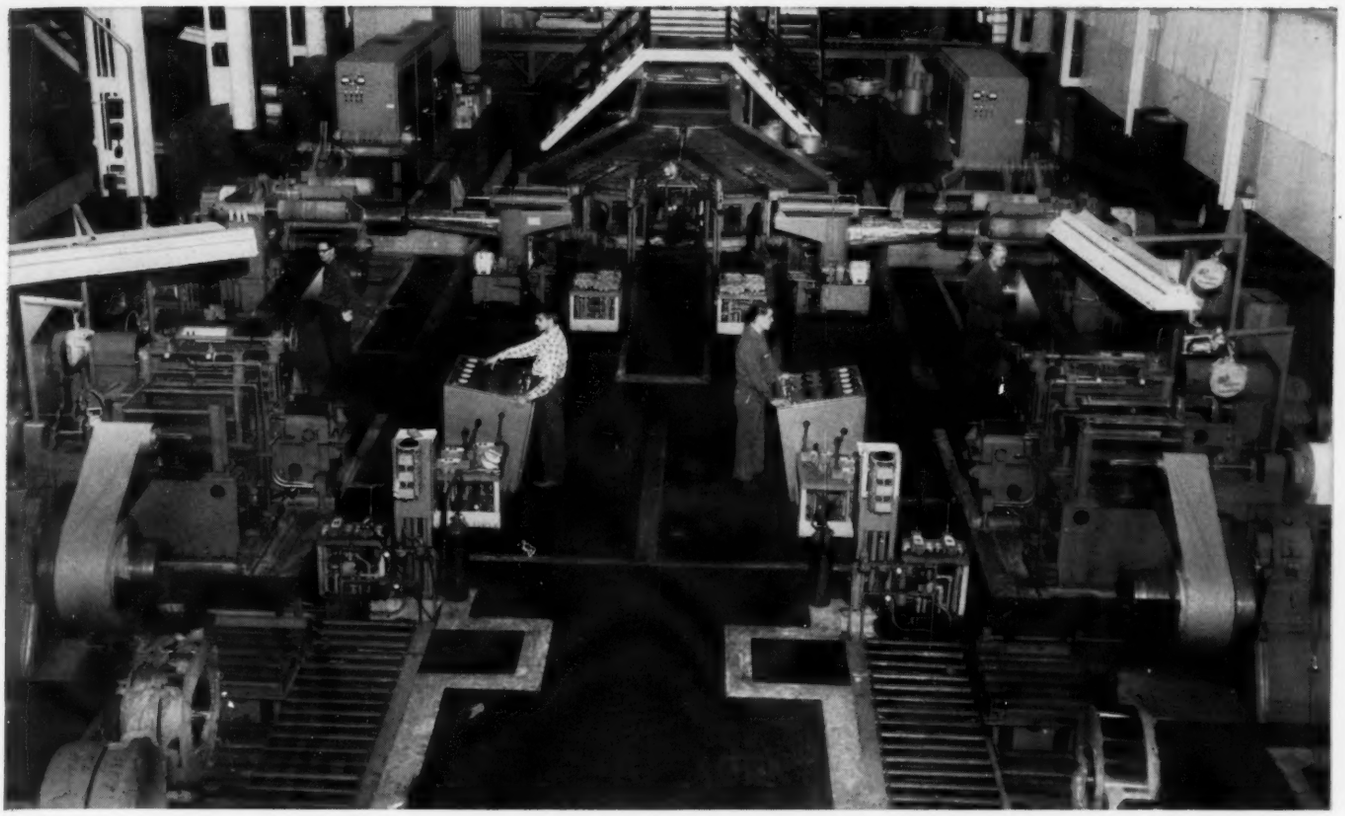
BULLETIN 715 SIZE 1
across-the-line, two-speed starter—with two overload relays per speed—in Nema Type 1 enclosure.

15-61-MR

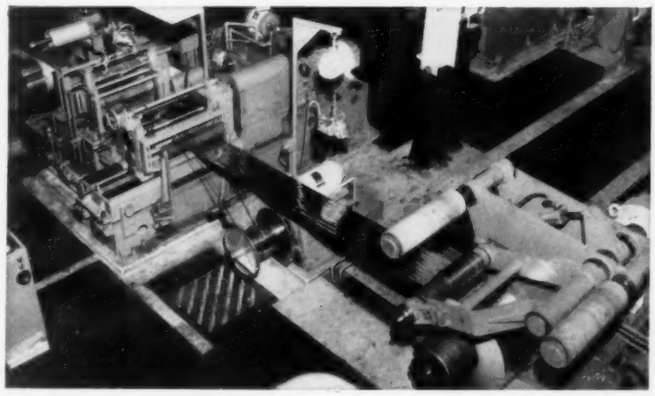
ALLEN-BRADLEY

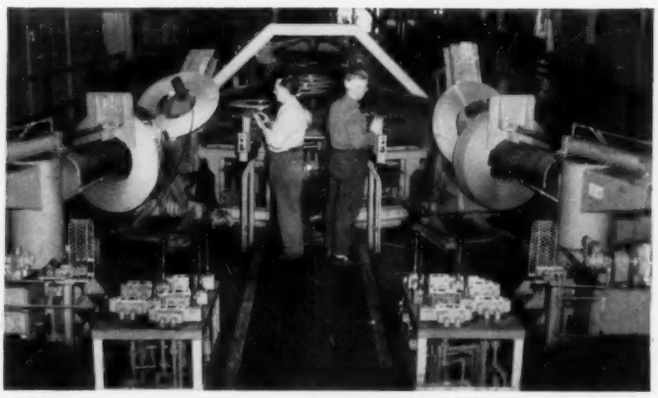
Member of NEMA

QUALITY MOTOR CONTROL



Predictable Performance...





SECO Slitting Installation, Superior Steel Division, Copperweld Steel Company, Carnegie, Pa.

is automatic—start to finish—with a SECO Slitting Line

SECO STEEL MILL EQUIPMENT

- Leveling and Shearing Lines
- Combination Edging and Flattening Lines
- Tension Reels for Strip Polishers
- Narrow Strip Grinding Machines
- Slitting Lines
- Multiple Strand Pull-out Rolls and Take-up Frames
- Strip Coilers (Up and Down Type)
- Traverse Reels for Narrow Strip
- Steel Coil Up-enders
- Scrap Ballers

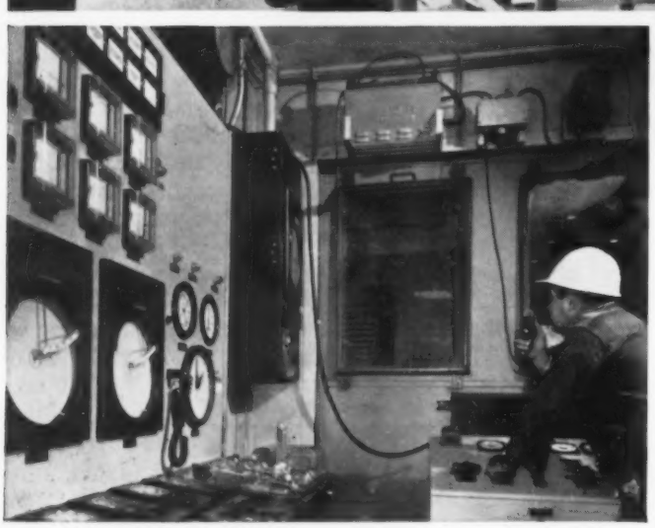
Affiliated with Lee Wilson Engineering Co., Inc.

Every operation in this *complete* slitting line by SECO—from entry to exit of coils—is fully automated. It was specifically designed and built by SECO to meet the maximum performance requirements of the Superior Steel Division, Copperweld Steel Company, Carnegie, Pennsylvania.

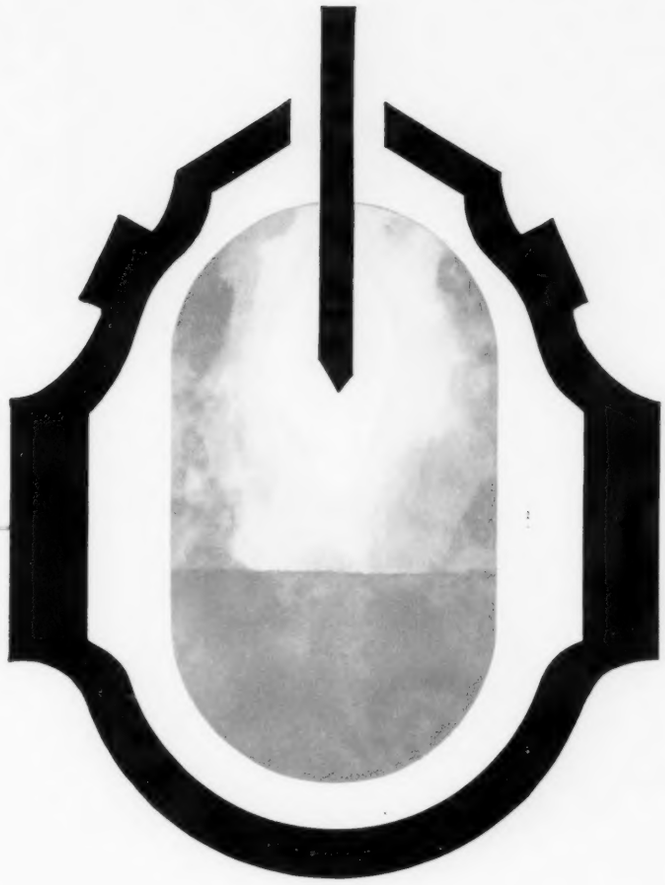
SECO's staff of experienced sales engineers, specialists in production problem solving, are prepared to show you how you can get "predictable performance" in *your* operation—whatever your requirements. Call or write today. West Coast representative: United Machine Tool Company, Los Angeles, California.

STEEL EQUIPMENT COMPANY

P. O. BOX 737, WARRENSVILLE STATION • CLEVELAND 22, OHIO



At Kaiser Steel Corporation, Fontana, California, this Honeywell system helps double plant capacity by controlling oxygen mass flow, lance position, lance cooling water temperature and pressure, and other critical variables. At left, an operator watches charging of one of the three new oxygen converters from a window in the control pulpit.



Why did Kaiser select Honeywell instrumentation for its L-D process?

At the Fontana plant of Kaiser Steel Corporation, Honeywell instruments were selected for the new basic oxygen steelmaking shop. This new process required instruments that were accurate, reliable, and fast enough to deliver the precise integrated control needed.

Kaiser Engineers called on Honeywell to furnish the necessary control instruments.

If you're planning to use the oxygen process—in converter or open hearth—you'll find it profitable to have Honeywell design your entire control system, complete from primary elements to computer, and tailored to the particular requirements of your mill. Your nearby Honeywell field engineer can give you complete details. Call him today—he's as near as your phone.

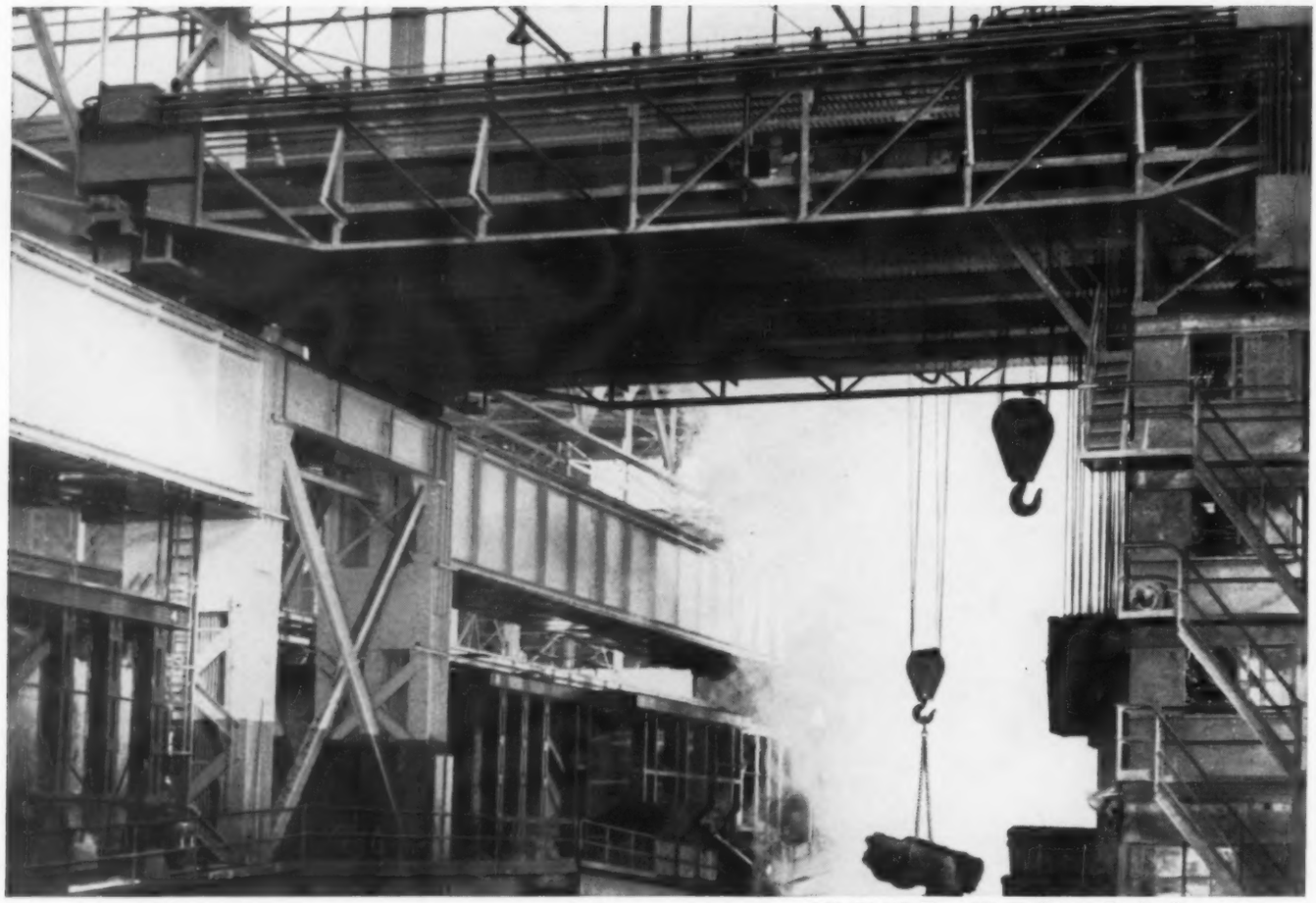
MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.



250/50/15 Ton, 67'-0" Span, Ladle Crane

At Kaiser's Fontana Works...

METAL IS KEPT MOVING WITH MORGAN CRANES

Highly efficient, dependable Morgan cranes help keep production moving smoothly at Kaiser Steel Corporation's Fontana, California, works.

In making plans for mill modernization or expansion, put a Morgan Engineering representative on your planning team. He'll give you facts on Morgan cranes and other Morgan mill equipment that will assist in speeding production and lowering your costs.

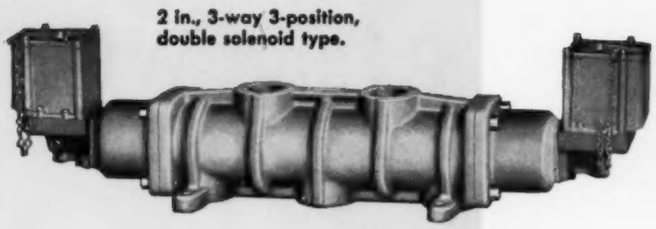
THE MORGAN ENGINEERING CO. *Alliance, Ohio*

E.O.C.I. MEMBER

Overhead electric traveling cranes, gantry cranes,
open hearth special cranes, blooming mills, structural mills,
shears, saws, auxiliary equipment and welded fabrications.

BIG CONTROL VALVES

up to 8 in. • 5000 psi



2 in., 3-way 3-position, double solenoid type.

8 in., 2-way 2-position, double pilot cylinder type.

Need more flow capacity than you can get with the largest sizes available in most valve lines? There's an easier answer than resorting to costly multiple valving, or redesigning your system to suit flow limitations.

Hunt builds valves in sizes up to 8 in., with air flow ratings of *more than 32,000 cfm @* 100 psi pressure drop! In fact, you can choose from valves ranging in size from ⅛ through 8 in.; 2 and 3-way, 4-way 2 or 3-position; solenoid, remote-pilot or mechanically actuated; with a variety of optional mountings and features.

If control of large volumes of air, oil, water, or soluble oil and water at pressures up to 5000 psi hyd. is one of your requirements, it'll pay you to talk to your Hunt representative. His specialized knowledge can save you hours and dollars. Call him today.

HUNT

QUICK-AS-WINK® AIR AND HYDRAULIC

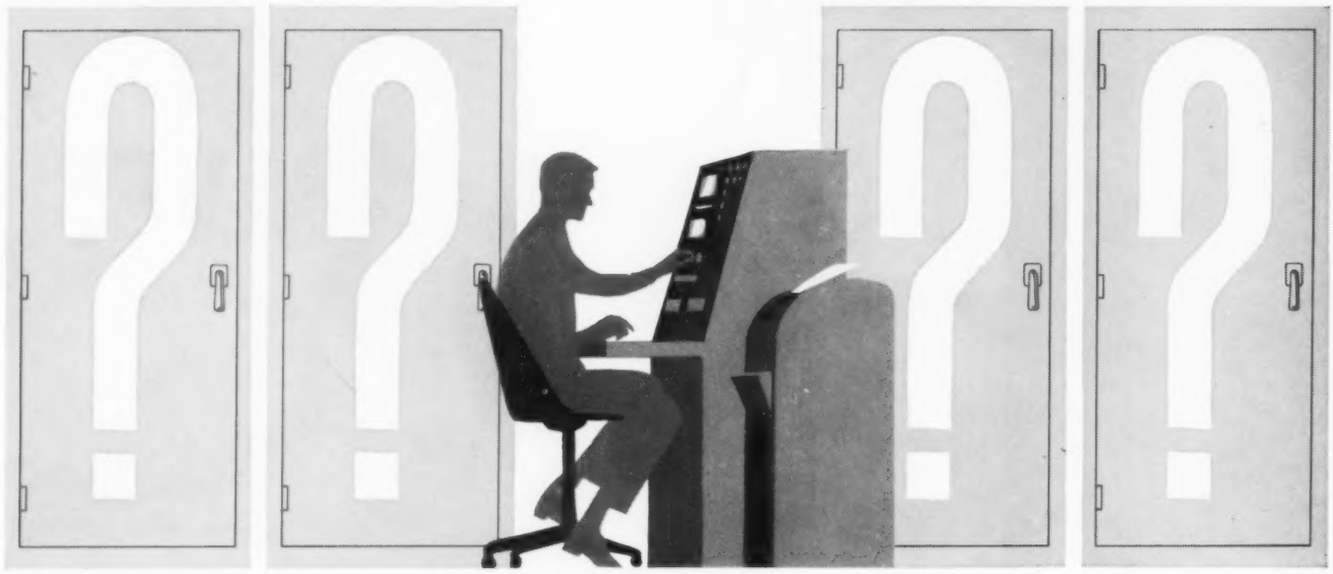
VALVES

HUNT VALVE COMPANY • DIVISION OF IBEC • SALEM, OHIO

For more information, write for Bulletin 603. Address Hunt Valve Company, Salem, Ohio, Dept. ISE-1061

3020

HOW MUCH automatic control ...and WHEN?



BAILEY 700 SYSTEMS can help you make sure . . . with step-by-step benefits

Many important — and profitable — improvements in steelmaking operations can be accomplished with analog and digital computer equipment.

Too much, too soon, however, can be costly — as can too little, too late. Intermediate stages of refinements in measurement and control are desirable and necessary. These not only can produce substantial benefits, but can demonstrate the additional improvements possible with further—or ultimately complete—automatic control. Bailey step-by-step automation assures against loss of prior investment.

Bailey engineers can help you determine optimum usage of *Bailey 700 Analog and Digital Systems* in your operations. They are equipped, by broad experience, to provide single-source responsibility from sensing and measuring instrumentation to complete automatic control. *Bailey 700 Systems* are installed, in operation, or on order, at locations from coast to coast.

Find out what this Bailey experience can offer you. Contact your Bailey District Office.

Where Bailey 700 Systems can aid steelmaking operations

SINTERING — to achieve maximum quantity and quality of output at lowest cost.

BLAST FURNACES — to provide lower coke rates and higher yields.

OPEN HEARTH — to increase production and control delays.

OXYGEN CONVERTERS — to maintain product quality at highest production rates.

PLANT UTILITIES—to reduce power and fuel consumption while still meeting plant requirements.

S122-1

IRON AND STEEL DIVISION

BAILEY METER COMPANY

1047 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS

400 MILLION TONS of HOT Metal Skill

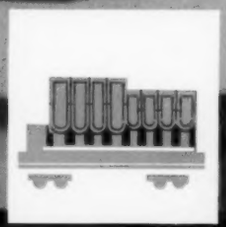
Now celebrating 80 years of hot metal experience . . . PECor is famous for equipment that stays-on-the-line making steel. Strong, safe, quality units backed by service which includes immediate response to field requirements!

May we consult with you in the planning stage—for standard PECor products or special fabrications?

BACKGROUND: ONE OF 15 PECOR BASIC OXYGEN VESSELS IN THE TAPPING OPERATION.

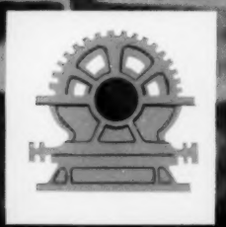
OXYGEN VESSELS

STEEL MILL CARS



LADLES

SPECIAL FABRICATIONS



Pennsylvania Engineering

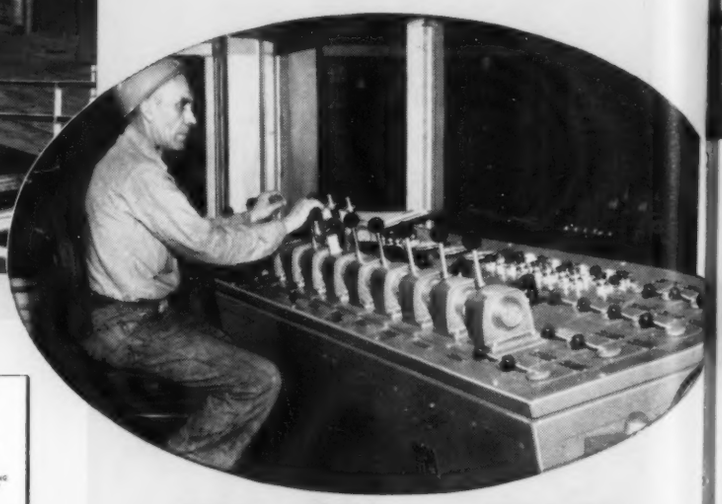
CORPORATION NEW CASTLE, PA.

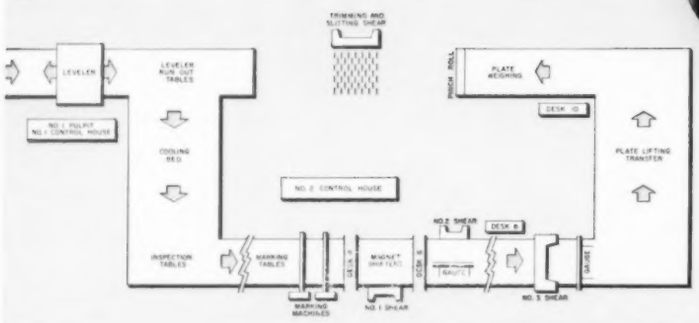
Sales Representatives: Wooldridge Company, Burlingame, Calif.
Fred Middleton Co., Inc., Birmingham, Ala.

Licensees: Ashmore, Benson, Pease & Company, Ltd., England
Kawasaki Dockyard Company, Ltd., Japan

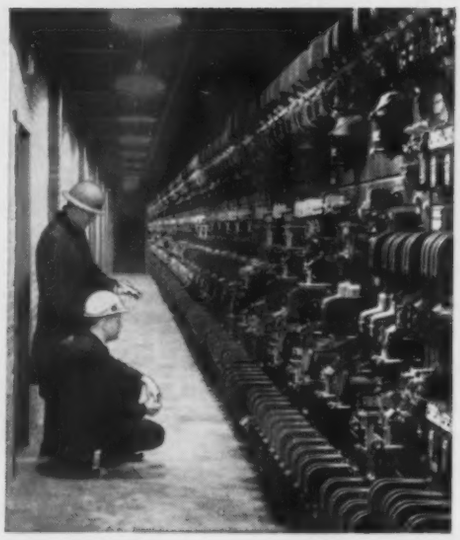
BUILDER OF AMERICA'S FIRST 15 OXYGEN CONVERTERS

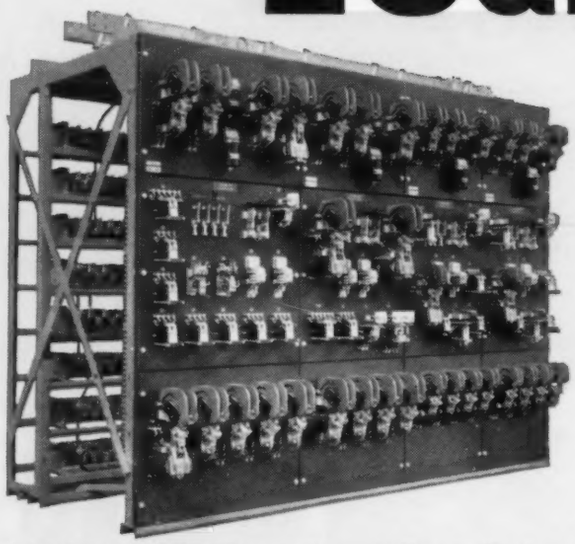
Initially, as shown in the flow diagram, plate starts through the Leveler. The operator, located on the second floor of the No. 1 control house, has a commanding view of the entry and delivery sides of the mill.





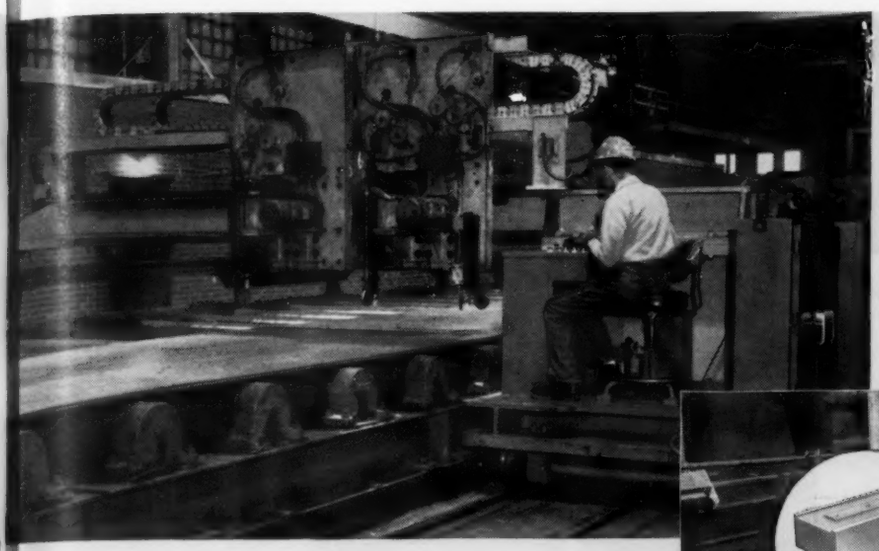
EC&M



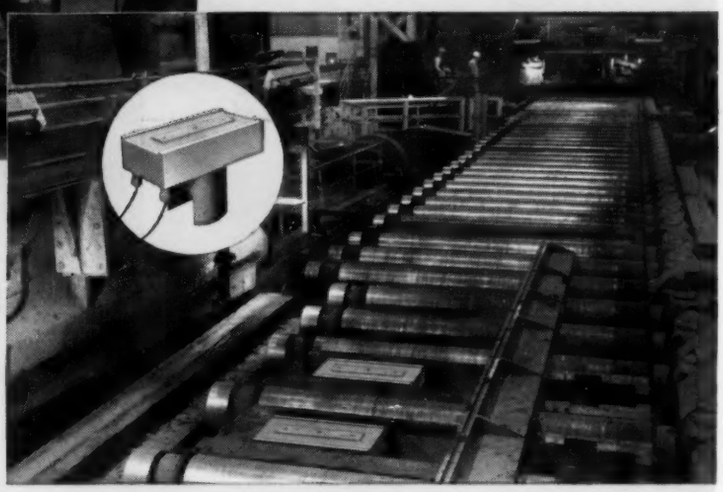


At left **is line-up of ECaM magnetic controllers in No. 2 control house. All controllers were factory-assembled** ***(above)*** **to speed installation and cut costs. Completely wired sections were placed in position and bolted together. Floor channels assured easy alignment. Overhead connecting bus also simplified and speeded installation.**

SQUARE D COMPANY
EC&M DIVISION • CLEVELAND 28, OHIO



"STATA" Control provides velvet-smooth operation from 0 to 200 feet per minute of the plate-marking machines. Compact EC&M control desk with knee room for the operator controls all motions and includes Productimeters showing lengths and widths for marking plates. A reversing switch enables the Productimeters to read in either direction, so that the marking machine works both ways...no non-productive trips.



ECaM Type P Magnet Shifters line up plate edges against gauge-bar for accurate shearing. To avoid surface mars, plate is raised above rolls during these shifting or shearing operations.

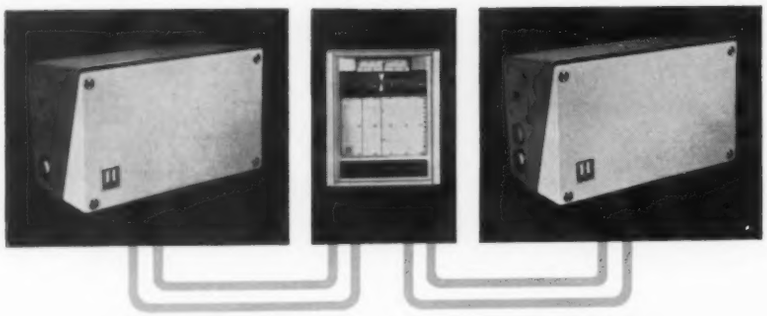
Control and Magnets help boost production, improve economies, on Bethlehem's 134" Plate Mill

Highlights of the 134" Plate Shearing Line at Bethlehem Steel Company's Johnstown, Pa., plant are shown on these pages. EC&M was selected to engineer and build all control apparatus and magnets and to coordinate motor requirements. Numerous control problems were effectively resolved by EC&M Control Engineering and the complete operation resulted in economical and efficient production of plate. EC&M's long experience in steel mill applications paid off in quick start-up with minimum tune-up time.

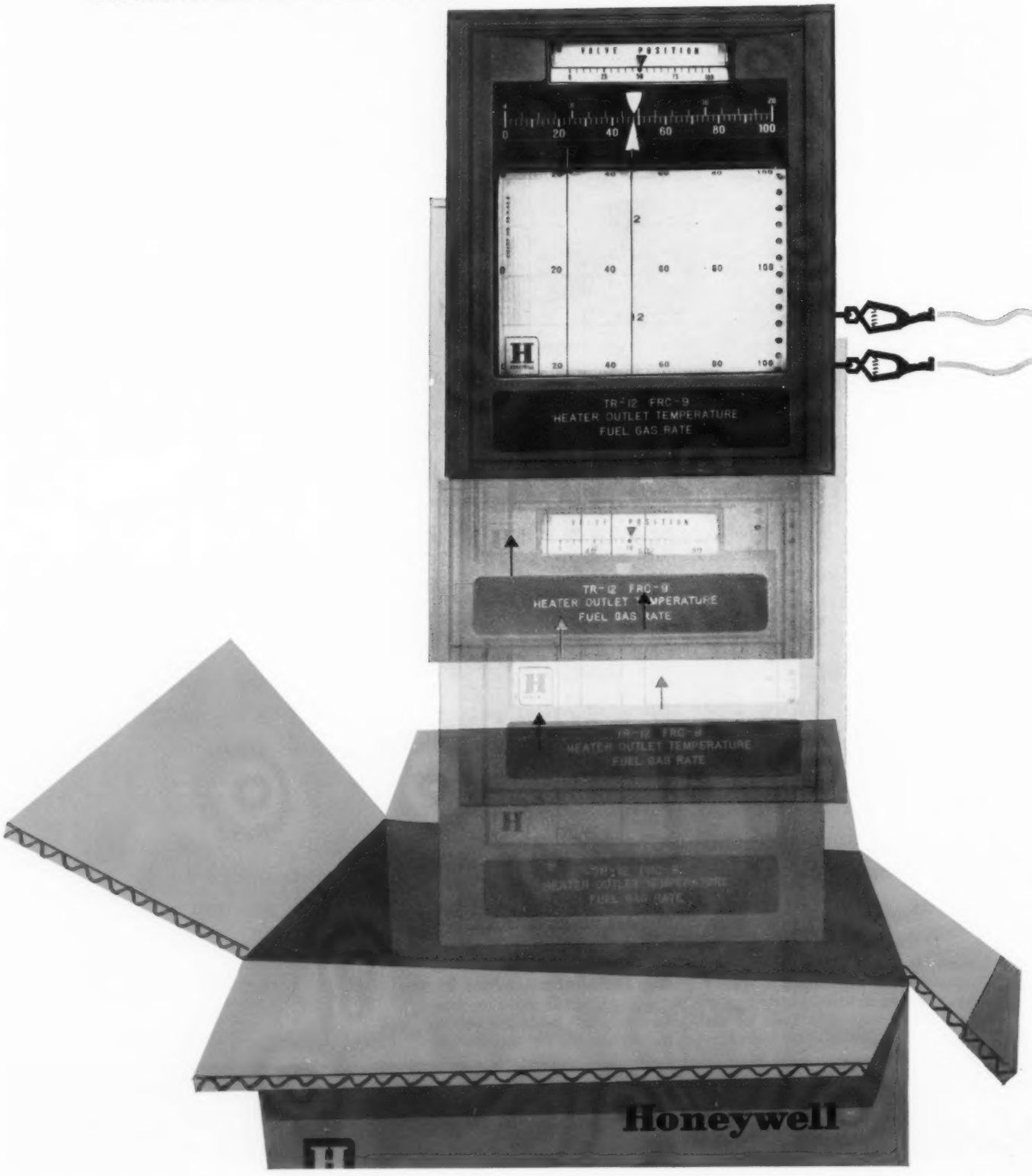
***The Complete Story** of this installation is told in detail in Brochure 6609-45*
Send for your copy

wherever electricity is distributed and controlled

7060



***ElectriK Tel-O-Set*—the true 2-wire system**



This "Loop Snooper" adds to the extraordinary ease of installation and maintenance you'll find in the *ElectriK Tel-O-Set* System. It's a portable test instrument that can accurately check . . . from the control panel . . . any *Tel-O-Set* unit in the field, to make sure signals are being received and sent exactly as they should be. Or it can operate and check a recorder chassis, indicator chassis or controller on the bench, with local power. The "Loop Snooper" removes trial and error from installation and maintenance.

SIMPLEST TO INSTALL, ADJUST AND MAINTAIN

The *ElectriK Tel-O-Set* System has many features that save time in getting on stream, and keep maintenance to a minimum. For example, all process connections are isolated from the inside of *Tel-O-Set* transmitter and transducer cases, so that you can mount, pipe and wire the instruments without removing their covers. Instrument chassis can be removed for servicing without breaking any external process or electrical connections. Standardized parts and extensive use of quick-connect and plug-in design cut downtime and spare parts requirements.

No external power is required at any field-mounted *Tel-O-Set* instrument; line power is connected only at the receiver. Two-wire d-c transmission eliminates shielding and further reduces installation costs. The 4-20 milliamp signal range gives a *live* zero through the use of readily available reliable transistors.

Your nearby Honeywell field engineer can tell you how *ElectriK Tel-O-Set* advantages relate to your particular control requirements. Call him today . . . he's as near as your phone. Or write to MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Massachusetts.

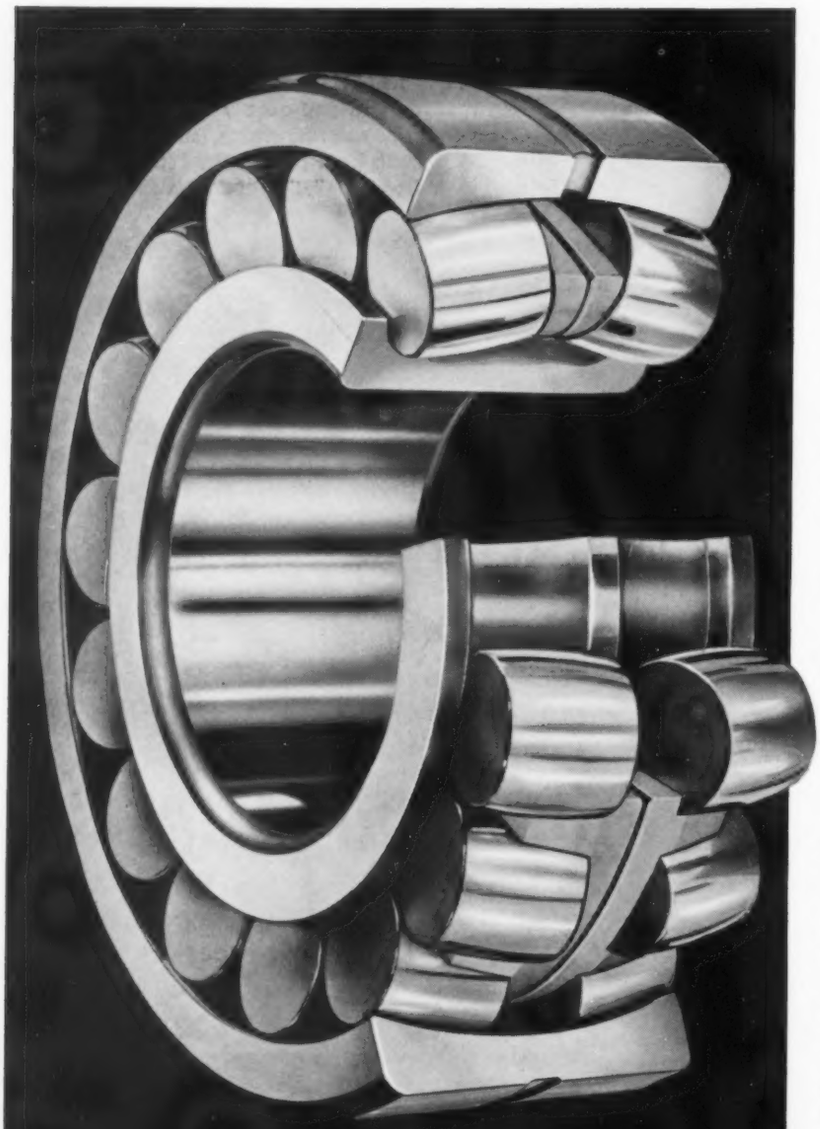
Honeywell

H HONEYWELL *First in Control* SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

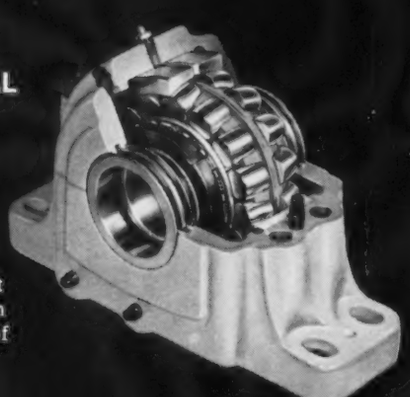
LINK-BELT SPHERICAL ROLLER BEARINGS:

measure these design values in terms of your applications



LINK-BELT SPHERICAL ROLLER BEARING PILLOW BLOCKS

Made with sturdy gray iron or super-rugged cast-steel housings. Adapter mounting types for shafts from 1 7/16" to 10½" and direct-shaft mounting types for shafts from 1.7717" to 11.0236". Choice of rugged steel, multi-labyrinth or Dacron-contact seals.



GREATER CAPACITY!

The reason? *More rollers, larger rollers!* Bearing capacity depends primarily on effective roller Length, roller Diameter and Number of rollers (L x D x N). And Link-Belt offers the *largest effective roller complement* for all sizes of spherical roller bearings . . . rated according to accepted formulas of the Anti-Friction Bearing Manufacturers Association. This increase in LDN values provides extremely high capacity . . . and in users' evaluation, it adds up to far longer bearing life.

GREATER DURABILITY!

With balanced proportion design, Link-Belt spherical roller bearings possess durability characteristics that exceed the bearing industry's exacting requirements. Optimum balance of rollers, inner and outer rings must be obtained for increased bearing capacity . . . yet overall bearing dimensions must conform to an established international standard boundary plan.

Wrap-around, completely contoured retainers also contribute to durability through positive roller guidance and spacing. Precision-machined of centrifugally cast bronze, these husky retainers are far stronger than stampings or sand castings.

GREATER PRECISION!

Link-Belt spherical roller bearings are made in the world's most modern bearing plant . . . with the most-advanced tools and techniques known to industry. A rigid quality control program leaves *nothing* to chance. Each Link-Belt bearing is subjected to *758 actual inspections*. Microsmoothness and precision are continuously scrutinized by automatic machines. Result: these bearings have been specified by leading manufacturers of cranes, shovels, graders, vibrating screens, and steel mill, paper mill and foundry equipment . . . and for high-precision applications such as embossing rolls, printing presses and torque converters.

SEE BOOK 2760 for further precision, durability and high-capacity features. Contact your nearest Link-Belt office or authorized stock-carrying distributor. Look under BEARINGS in the Yellow Pages of your phone book.

LINK-BELT

SELF-ALIGNING BALL AND ROLLER BEARINGS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Warehouses, District Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13); South Africa, Springs; Switzerland, Geneva. Representatives Throughout the World. 15,691

HIGH-PRESSURE JETS BLAST DEPOSIT-PACKED BUNDLES CLEAN AS NEW

The high-pressure jet unit below is blasting solidly-caked deposits from a heat exchange bundle . . . removing substantially all traces of deposits throughout the bundle, without cutting it apart!

Nation-wide Dow Industrial Service developed this automatic unit to remove scale, coke and asphalt deposits without metal erosion or wall thinning. This is just one of many advanced tools and techniques developed by Dow Industrial Service to clean equipment of every kind... boilers, pipelines, chemical process equipment, towers, scrubbers.

D. I. S. engineers first analyze your problem, then pick the most effective cleaning method . . . whether chemicals, steam, jet, foam, or other means. D. I. S. tailors the technique to give you most value per dollar.

In addition, D. I. S. offers complete consulting laboratory service for water treatment and waste processing problems, backed by the technical resources of The Dow Chemical Company.

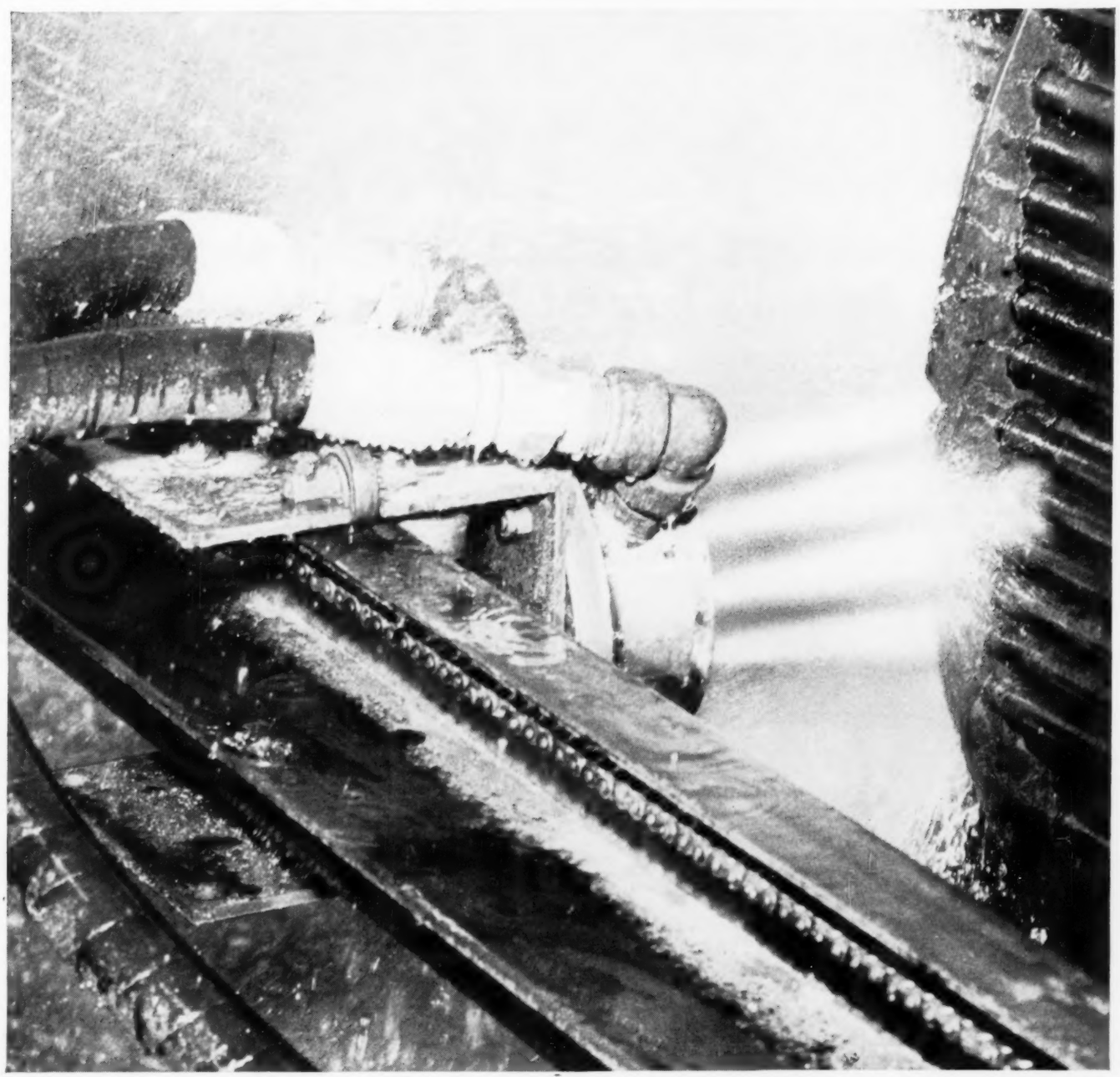
D. I. S. is a nation-wide industrial service . . . and offers "total" cleaning. For cleaning equipment of *any* kind, *anywhere*, call D. I. S. We'll be glad to show you how to set up a year 'round cleaning program to *keep* equipment operating at top efficiency. Write or call DOW INDUSTRIAL SERVICE, 20575 Center Ridge Road, Cleveland 16, Ohio.

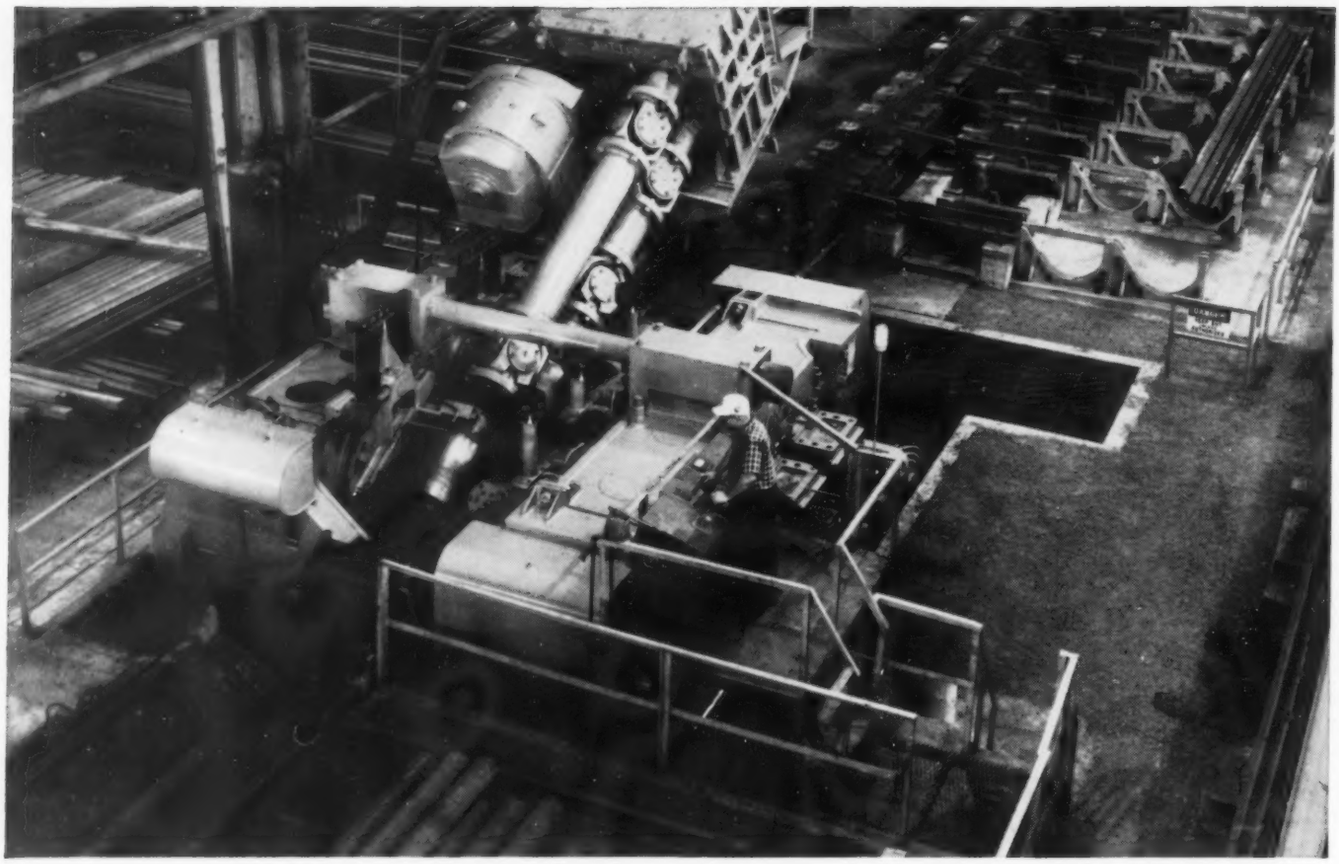
Dept. I&SE 10

DOW

Automatic jet unit removes bundle deposits, without dismantling.

DOW INDUSTRIAL SERVICE • Division of The Dow Chemical Company

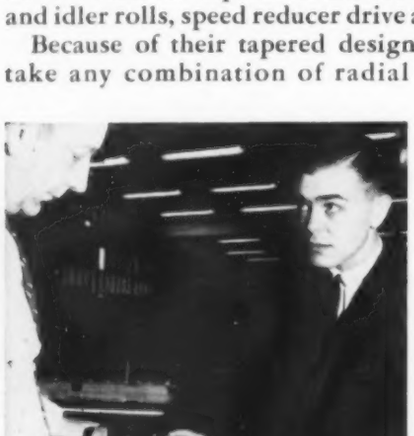




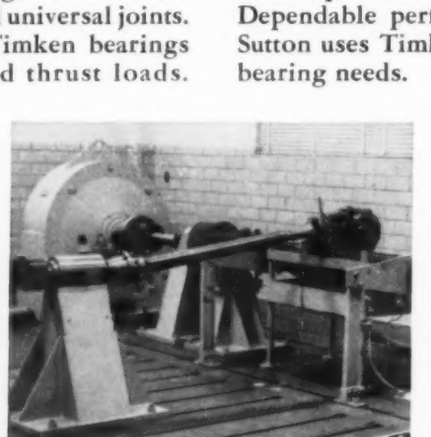
Timken® bearings withstand extreme shock loads on Sutton's largest bar straightener

When the Sutton Engineering Company designed this "5BC" straightener for Sheffield Div. of Armco Steel Corp., they wanted to be sure it would withstand the shocks of straightening large diameter heat treated alloy steel bars at speeds of 30 to 90 f.p.m. and with high precision. Their solution for trouble-free performance—Timken® tapered roller bearings for the drive and idler rolls, speed reducer drive and universal joints.

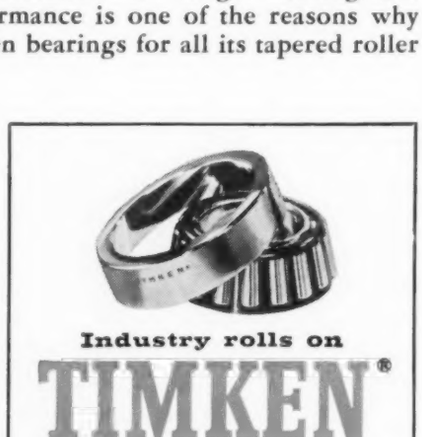
Because of their tapered design, Timken bearings take any combination of radial and thrust loads. Timken bearings roll true, practically eliminate friction, save input power. And because of Timken bearings' higher capacity, Sutton engineers could save space by keeping bearing sizes to a minimum. What's more they had the advantage of using the new Timken pin-cup bearings in the drives to prevent creeping, assure positive lubrication and longer bearing life. Dependable performance is one of the reasons why Sutton uses Timken bearings for all its tapered roller bearing needs.



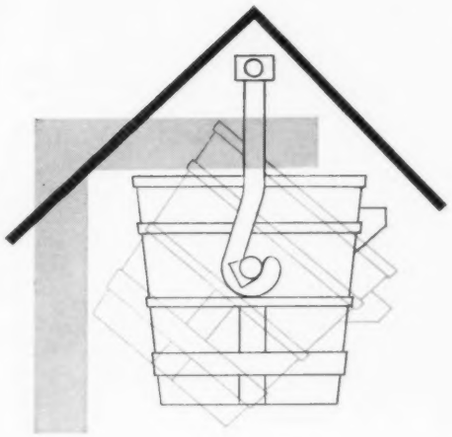
ON-THE-SPOT engineering service from our graduate-engineer salesmen solves bearing problems. They can help you select the one bearing from thousands that is exactly right for each position.



RESEARCH AND DEVELOPMENT, typified by the dynamometer above help keep Timken bearings your No. 1 bearing value. The data it provides helps increase performance of Timken bearings.



The Timken Roller Bearing Company, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits. Canadian Division: Canadian Timken, St. Thomas, Ont.



STEEL ANGLES

PRODUCTIVITY is one of the most significant terms in our economic and industrial vocabulary today. Yet, despite its broad use, it is a relatively new concept. Scarcely found in the literature in the 1920's, it began to appear during the late 1930's, and in the Post World War II period, it was a by-word at virtually every collective bargaining session in the major industries.

Increasing productivity has been advanced as a panacea for most of our economic ills, for it has been said if we can continue to improve productivity, wages and profits can increase, and it might even be possible to lower prices. An improvement in productivity means greater efficiency in the application of labor, as well as in the use of raw materials and capital equipment and this will benefit the entire economy. However, there are problems that have arisen in connection with the measurement and analysis of productivity and these should be treated if the concept is to have its maximum value.

Much has been done on the study of productivity, but since it is a concept of recent vintage, it should not surprise us that there are shortcomings and limitations which require considerably more thought and development.

Two areas which require attention are closely related. They are: the actual measurement of productivity itself; and the analysis which must go with the measurement in order to get at the causes of any changes.

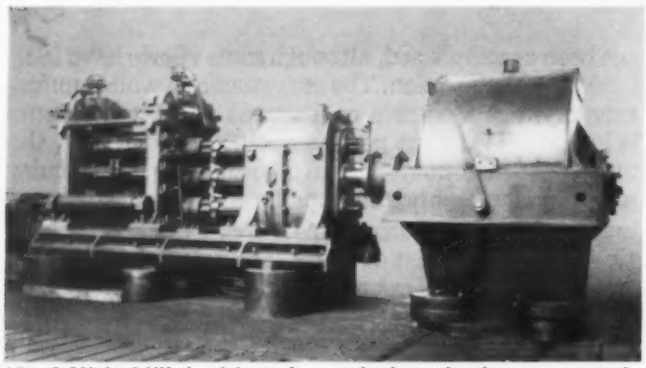
In respect to the measurement itself, productivity is a relationship or a ratio between the input factors of production, namely, raw materials, labor and capital equipment, and the resultant product or output. Thus there must be some attempt made to measure all three input factors in relation to the final product. To date it has not been accomplished, although some efforts have been made in this direction. The measurement, which, unfortunately, has become a consecrated and accepted one, is in terms of output per man-hour, or conversely, the number of man-hours required to produce a particular unit. This represents labor input and it has been heartening indeed to see a remarkable increase in labor productivity during the past 40 years. The period from 1919 to 1939 witnessed an increase of almost 100 per cent in man-hour output, and since the close of World War II, this has continued to improve at roughly three per cent per year.

However, it is widely, if not universally recognized that labor's productivity increase has been due in great part to the application and installation of improved capital equipment. Technological advances during the period between the two wars were remarkable, and those that have occurred since the close of World War II have been little short of spectacular. Nevertheless, our productivity measurements only show these advances in terms of man-hour output. There is no direct measure of the influence of capital nor the improved type of raw materials that have been used in recent years. Raw materials, of course, vary with the industry. In the basic industries such as iron and steel, copper, aluminum and petroleum they must be found in nature, thus their quality is very often a matter of chance. However, in recent years, low-grade raw materials have been beneficiated to a point where they are now acceptable. This, quite naturally, required additional capital investment and the application of labor.

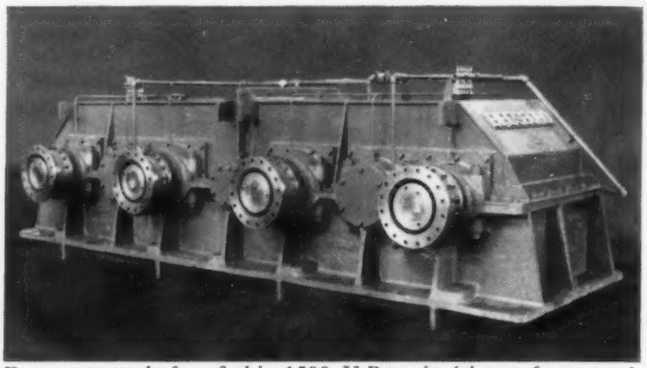
In other forms of manufacturing such as the automobile and appliance industries, the raw materials are a manufactured product, and through the years they have improved in quality, yet this improvement, along with the capital investment in these industries, does not show up in productivity measurements. Nevertheless, quality improvement and capital investment are vital to the advance that has taken place in productivity, and our concept, as well as the measurement, must include them in some way or it will be not only inadequate, but misleading.

In lieu of such a complex measurement, which admittedly is difficult to achieve because of the quality factor and the great fluctuation and variety of capital equipment, we might pay closer attention to an analysis of the reasons of increased productivity. Unfortunately, in many of the areas where productivity measurements are used for policy purposes, the bare figures become a source of discussion and debate, while the reasons behind the indices fall into obscurity, if not oblivion.

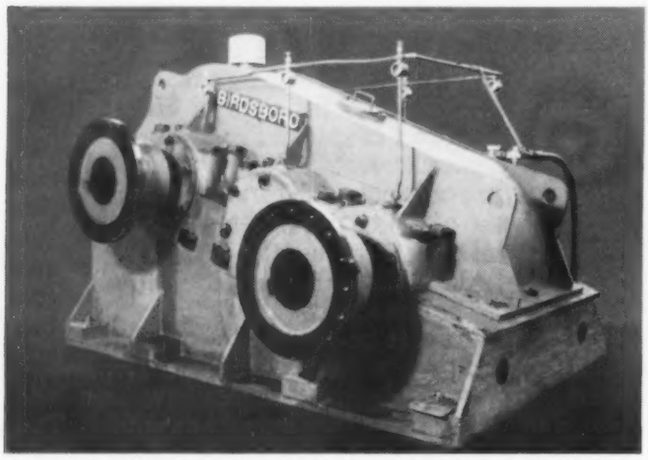
With every productivity measurement in a particular industry, and it is well for us to confine measurements to an industry—for here the analysis becomes more meaningful than it does on a national scale—there should be careful analysis of the causes for the fluctuations in the measurement. There might be several such causes: new capital equipment, better utilization of present equipment, better organization, more fruitful application of labor, etc. Such an analysis makes it possible for productivity measurement to be used in a practical way for it gives the relationship of cause and effect. Something like this would tend to make our concept and the measurement more valuable as a tool for policy and decision. ▲



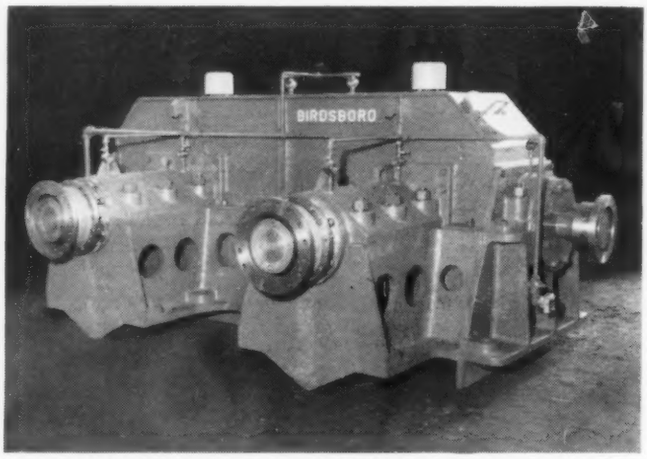
18" 3-High Mill is driven by a single reduction two speed, 1,000 H.P. Gear Drive. Speed changes are made by manually shifting a jaw type clutch on the output shaft.



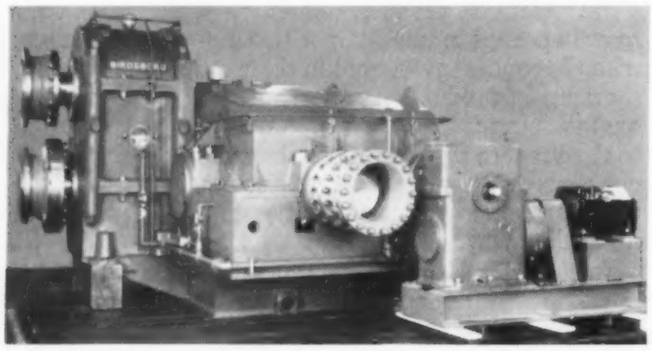
Four output shafts of this 1500 H.P. unit drive a four stand Continuous Mill with the proper speed increase for each stand.



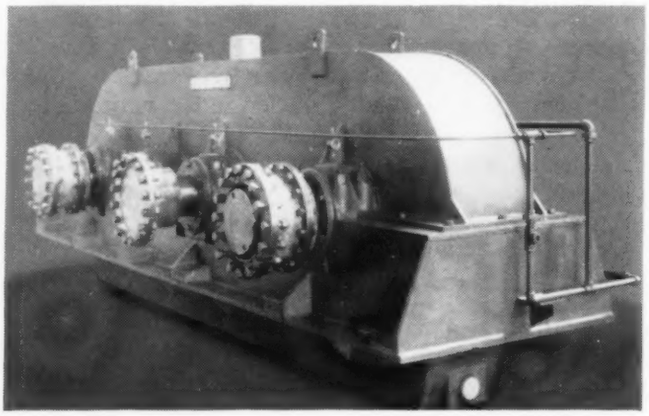
900 H.P. Single reduction double output Gear Drive is contained in a welded steel case. Output shafts on two levels, permit low floating shaft to pass beneath repeater to next stand of Cross Country Mill, driving mill in opposite direction.



Two 400 H.P. motors can transmit their entire power to either drive, for rolling heavy sections, or by disconnecting the bevel gear units each motor can drive a stand independently for looping.



A 3000 H.P. Drive has two output shafts for driving two 20" Mills, one directly and one through a low shaft and four-high Pinion Stand. First reduction is spiral bevel to conserve space in mill building. Second reduction has two ratios with a gear tooth clutch to give alternate output speeds of 76 RPM, or 155 RPM. Inching drive is provided to back out cobbles, and to facilitate coupling up. This drive is connected through air disc clutch for rapid remote controlled engagement.



A single 1250 H.P. motor drives a three stand 14" Cross Country Mill through a single reduction herringbone gear train. All gearing is carried on anti-friction bearings and lubricated by circulating oil for long, wear-free service.

SPECIAL MILL GEAR REDUCTION UNITS

designed and built by

MM 5-61

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Construction was started in 1951 on Chiba works of Kawasaki Steel Corp., using an 800-acre site reclaimed from the bay. Now of 2,200,000 ton annual capacity, it will be doubled when oxygen converters, now under construction, go into operation.

A Look At Steel In Japan

by T. J. Ess

. . . . Japan is planning to be the third largest steel producer in the world . . . . much has been accomplished in that direction and much more is planned . . . . gratitude must be expressed to the Japanese steel companies and the Japan Iron and Steel Federation for their courtesy, hospitality and help in making the author's inspections possible and pleasant . . . .

THERE may be a steel plant in Japan that has no construction project under way. If so, the writer failed to find it in a recent inspection tour of 13 of Japan's largest. What he did find was an industry that, in ten years, has built a prewar annual capacity of 8,500,000 tons (all tonnages are net tons) badly battered by war damage, up to a present capacity of about 30,000,000 tons per year. Furthermore, it is operating at capacity and planning to almost double that capacity in the next ten years.

From 1951 through 1956, a $355,000,000 program put steel capacity up to 12,700,000 net tons. In a second program, running through this year, eight blast furnaces, 17 oxygen converters, six blooming mills and four hot strip mills, with auxiliary equipment, were installed at a cost of $1,900,000,000. Between 1955 and 1959, four new "green-field" integrated plants were built.

About a year ago, the Japanese government announced a "double national income" program, which optimistically presumes that the gross national product of Japan should increase from $36,000,000,000 for 1960 to $72,000,000,000 in 1970. The steel industry's part in

this program is estimated to be expansion of the annual ingot capacity to 53,000,000 tons—49,500,000 for domestic use; 3,500,000 for export. This has been mapped out with capacities as follows:

	Net tons per year	
	1960	*1970*
Open hearth	15,500,000	16,000,000
Oxygen converter	3,450,000	27,500,000
Electric furnace	4,850,000	9,500,000
Total	23,800,000	53,000,000

Pig-iron capacity will be increased from about 14,000,000 to 38,500,000 tons per year, which will mean 30 to 40 new blast furnaces.

It is interesting to note that open hearth capacity will remain practically the same. Electric furnace capacity will be doubled, but oxygen process capacity will increase eight-fold. The ratio of pig iron to crude steel will increase considerably above the present 58 per cent.

The cost of all this is estimated at $8,300,000,000, including modernization of existing facilities. Large loans have been made for the expansion already accomplished and more will be needed. Altogether, with the high interest rate prevailing, they will make a formidable burden for the industry.

The additional steel will be used, according to estimates, by increases in the consuming industries ranging from 46 per cent in mining to 326 per cent in electrical machinery. Among other large increases are automobiles, 308 per cent; industrial machinery, 306 per cent; appliances, 400 per cent; construction, 168 per cent; engineering work, 187 per cent and wire products, 136 per cent.

The plan presumes that the per capita consumption of rolled steel will grow from the present 450 lb to 970 lb, which exceeds most countries of the world and begins to approach consumption in the U. S.

The plan is ambitious. Perhaps, even with the enthusiasm and energy of the Japanese, it is overly optimistic. It does not seem possible that Japan itself, with its relatively small domestic market for heavy consumer goods, can absorb the doubled production. A small electric refrigerator costs three to four months' pay and a small automobile, 30 to 40 months' pay.

Success, then, will hinge on greatly increased exports of manufactured products, which will meet severe competition from the expanding industries of other countries. Even now, manufacturing costs in Japan are advantageous only when labor forms a large part of total cost. Materials are not cheap in Japan, and wage rates are going up.

Certainly, the next ten years will be interesting to watch. An annual growth rate of 8.3 per cent in steel capacity for the next ten years seems excessive until it is remembered that the annual growth since 1951 has been 15 per cent.

At present, the Japanese steel industry consists of nine integrated producing companies which account for something like 75 per cent of the total capacity, plus numerous small steelmaking plants and rolling mills.

So rapid is the expansion of the Japanese steel industry that capacity figures are likely to be out-of-date before they can be published. Table I shows the annual

Nippon-Kokan's new Mizue works, shown under construction in the foreground, is a flat-rolled facility. It will be completely integrated in the next few years. The company's Kawasaki works is in the background.

TABLE I
Annual Capacity, Net Tons

	Iron		Steel	
	1961 Directory	Present estimate	1961 Directory	Present estimate
Yawata Iron & Steel Co., Ltd.	4,251,000	4,500,000	6,722,000	7,250,000
Fuji Iron and Steel Co., Ltd.	3,619,000	4,300,000	4,527,000	5,451,000
Nippon-Kokan K.K.	1,765,000	2,285,000	2,830,000	3,393,000
Kawasaki Steel Corp.	1,513,000	1,513,000	1,872,000	2,994,000
Sumitomo Metal Industries, Ltd.	1,054,000	1,223,000	1,180,000	2,420,000
Kobe Steel Works, Ltd.	302,000	402,000	1,320,000	1,320,000
Nakayama Steel Works, Ltd.	542,000	542,000	1,015,000	1,015,000
Japan Steel Works, Ltd.	...	...	378,000	378,000

capacities of the companies whose plants were visited, as reported in the 1961 directory of the Japan Iron and Steel Federation and as estimated for present equipment and production rates. Several new facilities now nearing completion will soon make these figures obsolete.

By 1965, annual capacities as now planned will be:

	Net tons of ingots
Yawata	10,000,000
Fuji	8,360,000
Nippon-Kokan	5,164,000
Kawasaki	4,805,000
Sumitomo	3,676,000
Kobe	2,447,000

RAW MATERIALS

The Japanese steel industry depends heavily on imports of raw materials. Transportation makes these expensive. In 1960 the industry used 21,820,000 tons of ore and other iron-bearing materials, 14,566,000 tons of scrap and 12,800,000 tons of coking coal to make 13,085,000 tons of iron and 24,352,000 tons of ingots.

Of these materials, 74 per cent of the blast furnace charge material, 31 per cent of the scrap and about 52 per cent of the coking coal was imported. Table II shows the sources of iron ore, scrap and coking coal for the year 1960.

Japan has limited ore reserves, but large reserves of iron sand and pyrites. Every effort is being made to increase the use of the domestic materials. Imported ores cost $13 to $18 per ton at dockside in Japan. Of this, about 40 per cent is transportation cost. On the other hand, there is the advantage of being able to choose the richer ores. Imported ores may run 59 to 67 per cent Fe.

Although Japan has considerable reserves of coal, coking properties are not satisfactory and it is expensive, approaching $20 per ton. Hence, more than half of the coking consumption is imported, principally from the U. S. Imported coal costs $14 to $17.50 per ton, and gives improved results. The coal mix is about half domestic, half imported.

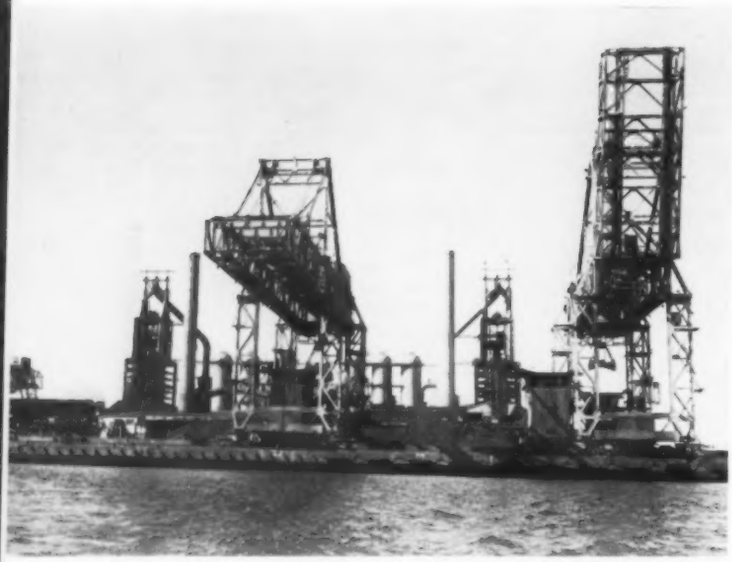
About two thirds of the scrap used is domestic, but considerable imports are necessary, principally from the U. S., at costs of $60 to $65 per ton. Price and the possibility of future shortages are behind the planned increase in the ratio of pig iron to crude steel, previously mentioned.

The industry used 3,320,000 tons of limestone in 1960, all of which was supplied from domestic sources.

To take care of the proposed expansion, Japan proposes to increase domestic ore supplies to 13,500,000 tons per year and to raise imports to 49,500,000 tons per year. South America is expected to provide over 10,000,000 tons a year of high-grade ore at a lower cost than now prevails. Imports from the U. S. and India will also increase. Use of domestic coking coal will increase to 10,200,000 tons per year and coal imports to 24,200,000 tons. Although scrap consumption for all purposes is expected to jump to 28,000,000 tons per year, scrap imports are expected to drop to 3,900,000 tons.

TABLE II
Sources of Raw Materials, 1960

	Net tons	Per cent	
Iron ore			
Imported from:			
Malaya	5,900,000	36.0	26.5
India	2,685,000	16.4	12.1
Goa	2,200,000	13.4	9.9
Latin America	1,360,000	8.2	6.1
Philippines	1,320,000	8.1	6.0
Canada	1,200,000	7.3	5.4
U. S.	910,000	5.5	4.1
Others	895,000	5.1	3.6
	16,370,000	100.0	73.7
Domestic:			
Ore	1,430,000	24.4	6.4
Iron sand	1,725,000	29.5	7.7
Pyrite cinder	1,600,000	27.3	7.2
Others	1,100,000	18.8	5.0
	5,855,000	100.0	26.3
	22,225,000		100.0
Scrap			
Imported from:			
U. S.	3,330,000	70.5	22.2
India	352,000	7.6	2.3
Others	1,020,000	21.9	6.8
	4,702,000	100.0	31.3
Purchased domestic	4,170,000	41	28.2
Circulating	6,020,000	59	40.5
	10,190,000	100	68.7
	14,892,000		100.0
Coking coal			
Imported from:			
U. S.	4,730,000	69.8	36.6
Australia	970,000	14.3	7.5
USSR	483,000	7.1	3.8
Canada	463,000	6.8	3.6
Others	132,000	2.0	1.0
	6,778,000	100.0	52.5
Domestic	6,110,000		47.5
	12,888,000		100.0



Every major steel plant in Japan has tidewater dock facilities. This view shows a portion of the port at Tobata works of Yawata Iron and Steel Co.

To handle the increasing imports of raw materials, practically every harbor is being deepened to allow larger carrier vessels to pull into the steel plant docks.

IRONMAKING

At the beginning of the year, there were 36 blast furnaces in Japan, operated in 13 plants by nine companies. Rated capacity totaled 13,183,000 tons. Several new furnaces have been put into operation in 1961. Actual iron production in 1960 was 13,085,800 tons, 26 per cent above 1959; 1961 production is at a rate of more than 16,000,000 tons.

The older furnaces have hearth diameters of 17 to 19 ft, but the new ones have been generally of 25 to 29 ft. Many of the smaller ones are due for enlargement. The use of carbon walls up to the tuyères is almost universal. At least one furnace has a carbon bosh.

The majority of the furnaces are a combination of American and German designs, with a free-standing stack, but with structural work which supports the top. Bronze cooling plates are usually installed well up into the stack, almost to the stock line.

Belt conveyors are widely used for handling the raw materials. The new plants have elaborate conveyor systems laid out in efficient systems controlled from a central point.

Because of the variety of ores received, bedding is common, as is careful sizing. Sintering is increasing. The industry average in 1960 was about 50 per cent sinter, but new plants to be built will raise this. Some furnace plants are already able to use 60 per cent or more sinter. Some of the sinter is self-fluxing or partially so. Most of the sintering plants are of traveling-grate design. A number of rotary sinter coolers are installed. Some pelletizing is also done, particularly at Chiba works of Kawasaki Steel Corp.

Most of the blowing equipment consists of conventional turboblowers, but a number of axial compressors have been installed.

High top pressure is beginning to appear but does not seem to raise too much enthusiasm, although several furnaces are to be rebuilt for high pressure. A few furnaces are running on an enriched blast of about 23 per cent oxygen. A few also have blast volume distribution by tuyère controls.

Blast temperatures are on the high side, many units running 1550 to 1750 F. Automatic stove changing is usual on the new furnaces, which generally have three stoves. One furnace was equipped with individual blast temperature control on each tuyère, but the equipment was not in use.

Fuel injection through the tuyères is just coming into the picture. No furnaces are operating in this manner, but several plants are planning to experiment with fuel oil.

The quality of the furnace charge is indicated by the fact that the industry average for 1960 was about 3075 lb of charge material per ton of iron. Limestone runs 285 lb per ton of iron and 165 to 170 lb of open hearth slag is also used. The result is a low coke rate, which averages about 1235 lb per ton of iron. The reported record is 960 lb per ton. The average just seven years ago was 1676 lb per ton. The U. S. averages for 1960 were 3418 lb of charge materials, 1498 lb of coke and 606 lb of limestone per ton of iron.

Probably because of the narrow gage of Japanese railroads, most of the hot metal cars are small and of open top design. Just recently, a few mixer or torpedo-type cars have been put into use. They are somewhat smaller than those used in the U. S.

The formula by which Japanese blast furnaces are rated is:

Annual capacity (metric tons) = 365 times the working volume (cu m)

Translated into English units:

Annual capacity (net tons) = 11.4 times the working volume (cu ft)

Ratings calculated in this manner are often exceeded by 10 to 40 per cent in actual production.

STEELMAKING

In the past, Japanese steelmaking has been based primarily on the basic open hearth process with a fair

This new 45 x 90-in. universal slabbing mill at Hirohata works of Fuji Iron and Steel Co. is typical of the modern equipment which has been installed.

Most of the blast furnaces in Japan use structural work to support the furnace top. This unit, at Tobata works of Yawata Iron and Steel Co., is rated at 1500 tons per day.

amount of electric furnace capacity. An installation of basic bessemer converters was made about 20 years ago but is not used now. Steel production in 1960 was approximately:

	Net tons
Open hearth steel	16,600,000
Electric furnace steel	4,910,000
Oxygen converter steel	2,900,000
Total	24,410,000

This is 33 per cent above the 1959 figure and made Japan the fifth largest producer in the world. Present production is exceeding this rate and figures for the first half of 1961 show Japan in fourth place with a 6-month production of 14,600,000 tons.

There are 148 open hearth furnaces in Japan, with a rated annual capacity of about 17,000,000 tons. Almost all of these are of basic refractory construction. By American standards, they are small, many being only 50 to 60 tons and the largest only 225 tons. Some are of tilting design. The average heat is about 105 tons, and the average production rate is approximately 20 tons per hr. Some plants, however, produce at rates of 30 to 45 tons per hr. Heat time ranges 3½ to 6½ hr, tap-to-tap.

Open hearth charges average 55 to 56 per cent hot metal, but a number of plants run this up to 60 and even 75 per cent.

Oil and coke-oven gas are the principal fuels, with reported consumptions quite low—many at 2,000,000 Btu per ton, one at 1,250,000. The industry average is 2,830,000 Btu per ton. In 1953, the average was 5,400,000 Btu per ton. However, oxygen consumption is quite high. The average is said to be about 640 cu ft of oxygen per ton of ingots, but all of the plants visited exceed this usage, with quite a few using between 1200 and 1450 cu ft per ton. It is almost universally introduced through lances through the wicket holes in all five doors. Each lance usually has its individual attendant. The introduction of oxygen in the open hearths has contributed greatly to the increase in Japanese production.

Some open hearth shops have already installed some type of cleaners to eliminate the heavy smoke resulting from the use of oxygen. Others are planning to install them in the near future.

Japan already has 17 top-blown oxygen converters in operation, with an annual capacity in excess of 6,000,000 tons. Many more installations are planned. In fact, this process is to form the major part of the planned expansion and will make up over 50 per cent of the expanded capacity.

The existing vessels range from 40 to 80 tons in heat size, but larger ones, up to 165 tons, are coming. They operate on an average charge of 81 per cent iron and 19 per cent scrap, although some plants use 28 to 30 per cent scrap. Oxygen consumption runs 1700 to 1850 cu ft per ton of steel. Heats are turned out quite rapidly, with tap-to-tap times ranging 33 to 40 min.

One plant that uses both the open hearth and the oxygen processes reports their oxygen converter operating cost to be $4.20 per ton less than their open hearth cost.

Annual productive rating of open hearth furnaces is calculated by the following formulae, which appear to be empirical:

Hot metal practice:

$$\text{Heat size in metric tons} \times 710 + 46{,}200 = \text{metric tons per year}$$

or

$$\text{Heat size in net tons} \times 710 + 50{,}820 = \text{net tons per year}$$

Cold metal practice:

$$\text{Heat size in metric tons} \times 480 + 24{,}400 = \text{metric tons per year}$$

or

$$\text{Heat size in net tons} \times 480 + 26{,}840 = \text{net tons per year}$$

Capacities calculated in this manner are often exceeded by 25 to 50 per cent in actual production, as the formulae do not fully recognize the effect of the use of oxygen.

There are about 300 electric furnaces in the Japanese steel industry, but most are of small size, with a total

capacity of 5,300,000 tons per year. Some larger furnaces (up to 90 tons) are being installed, and it is expected that the doubling of electric furnace capacity called for by the 10-year program will bring in more large units.

ROLLING

The new rolling mills that have been installed in Japan are preponderantly in the flat-rolled field, which is expected to make up an increasing part of the industry's product.

At present there are eight hot strip mills in operation with a rated capacity of 8,140,000 tons per year. These range from 36 to 86 in. wide, and include one continuous mill, six semi-continuous mills and one reversing mill. Under construction are an 80-in. semi-continuous mill, a 68-in. continuous mill and a 39-in. reversing mill, and others are planned. These will put Japan well up in the world's strip mill facilities.

Strip finishing facilities are being expanded with many tandem cold mills and continuous processing lines.

New rolling units also include a number of slabbing mills, several heavy plate mills and rod mills. Several wide-flange beam mills are going in. All of these units are of modern design and are equipped with the latest developments in drives, control and auxiliary equipment. Several of the reversing units have card-programming systems. Mill equipment is of American, German and Japanese manufacture, with some of the last made under foreign licenses.

If one can ignore the strange-looking signs and markings, it is difficult to tell whether the new mill installations are in Japan or Europe or the U. S. They are fully the equal of those in other countries, although they do not seem to be pushed as hard as the American mills. Mill crews on the modern units do not appear to be much larger than those in the U. S.

There are many old rolling units, particularly merchant or "section" mills, that leave much to be desired. Many are of the Belgian layout and require large crews. Many rod mills have completely manual operation in the finishing end. There are also numerous sheet mills, both manual and mechanized. Silicon sheet facilities are being expanded.

Tubular production comes from mills which span the entire field. Some seamless mills have been overhauled and are modern in every respect. Some new continuous butt weld mills have been started up, as well as numerous electric weld mills. U-O press units are in use for electric-welded line pipe. The extrusion process is also used. Facilities for the production of tubular products are expanding.

Few blooming or slabbing mills in Japan have flame scarfing machines. Some operators believe that hand scarfing with existing wage rates is more economical than machine scarfing with its higher material loss. Quality considerations, however, are forcing several mills into the use of scarfing machines.

This 55-ton oxygen converter is operating at Kokura works of Sumitomo Metal Industries, Ltd. This method of steelmaking is expanding tremendously in Japan and will eventually form 52 per cent of total capacity.

MISCELLANEOUS

All of Japan's major steel plants are located on tidewater sites, some of which have been reclaimed from the sea. Harbor facilities are being improved and enlarged to handle the larger vessels, up to 60,000 tons, which the expansion program will require.

Plant layouts of some of the older plants show evidence of having "just grown," but the new plants are well laid out for efficient operation. In building a new plant, the Japanese usually start with the erection of some rolling equipment and follow with pig iron and steelmaking facilities. It is felt that this brings quicker returns on the construction expenditure.

The enthusiasm of the Japanese for new techniques, new devices and new developments is evident in all new installations.

Fuel is expensive. Natural gas is not available. Heavy oil is the basic fuel, with 1960 consumption totaling 605,000,000 gal. Most integrated plants mix coke-oven gas and blast furnace gas for various heating applications. Some plants sell coke-oven gas and blast furnace gas to utility companies.

Most of the large plants have considerable power generating equipment, providing 25 to 50 per cent of their

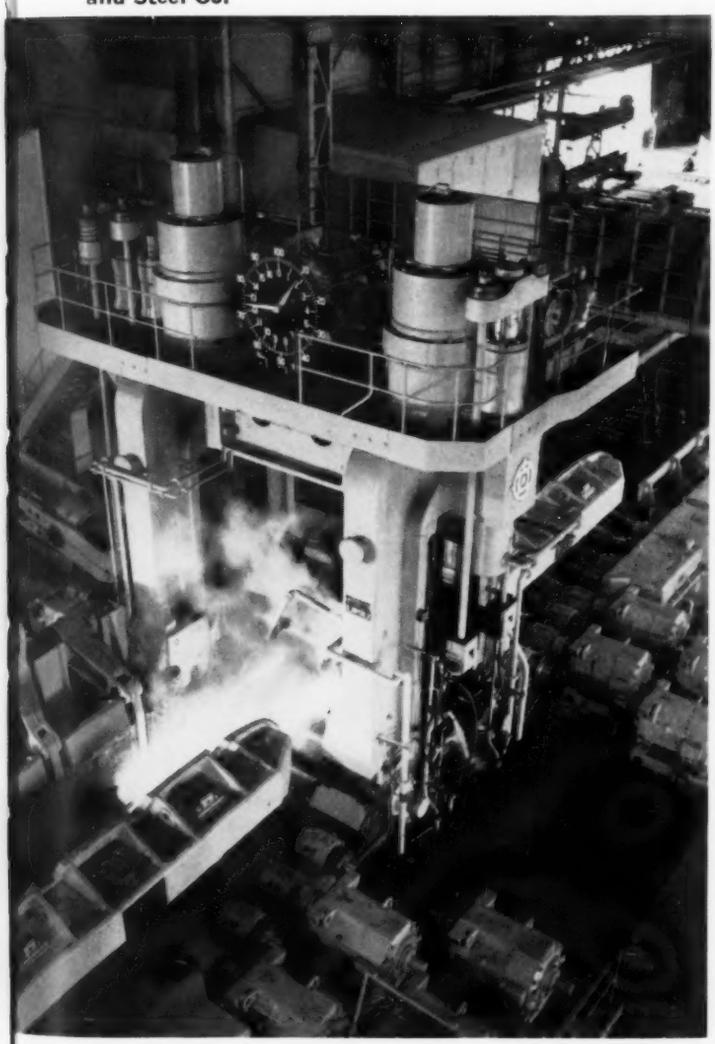
power requirements. Total power consumption of the iron and steel industry in 1960 was 13,827,457,000 kwhr, including, 3,032,200,000 kwhr for ferroalloy production. Eliminating this item, consumption per ton of ingots was 488 kwhr per ton, This is considerably higher than the U. S. figure of 305 kwhr per ton, but it apparently includes the consumption of foundries and fabricating plants.

In some locations, fresh water is rather scarce. Plants in such locations are forced to take as much as 80 per cent of their service water requirements from the salt water in the harbor. Lakes and rivers furnish fresh water, which in some cases makes up 80 per cent of the plant usage. The use of salt water for blast furnace cooling is general. Some plants have projects under way to obtain more fresh water.

Plant housekeeping varies from plant to plant. Some spots looked pretty poor, the majority of plants were not too bad, but few would satisfy some of our American fanatics.

Considerable effort seems to be put into the safety program, but the use of a lot of the safety equipment almost universal in the U. S. is rather sketchy in Japan. The frequency rate in the Japanese steel industry has improved greatly in recent years but still stands between eight and nine injuries per million man-hours worked, well over twice the U. S. rate of 3.14.

This 46 x 115-in. high-lift slabbing mill was built in Japan. It is installed at the Muroran works of Fuji Iron and Steel Co.



Most of the research of the iron and steel industry in Japan is done by individual companies. There is no national or cooperative research organization such as is found in European countries. The larger companies are developing fairly extensive research departments, topped by Yawata Iron and Steel Co. with their Technical Research Institute, employing 700 people.

A number of the plants seem to be particularly blessed with a good supply of intelligent young engineers and supervisors who should be of great assistance in expanding and improving the industry.

Technical assistance programs with various American and European steel producers are maintained by several of the large companies.

LABOR

The Japan Iron and Steel Federation reports the 1960 employment of the industry at 233,854 process workers and 43,344 technical and clerical workers. Workers are hired pretty much for life. Labor unions are organized on a plant basis. Of approximately 185 such unions, with 210,000 members, about 57 unions with 137,000 members are affiliated with the Japanese Federation of Iron and Steel Workers Union, established in 1951. Thus far, the national union is principally of a political nature. Bargaining is usually carried on between individual companies and their respective plant unions. Labor-management relations are rather paternalistic and, for the most part, pretty good. There are no general strikes. Individual plants may be struck for two or three days, with the duration often announced before the strike starts. During the visit to one plant, an announcement was made that there might be a walkout because the union felt the mid-year bonus was not big enough.

WAGES

Average wages in the iron and steel industry for 1960 were reported by the Ministry of Labor as 34,901 yen ($97) per month for production workers and 46,256 yen ($127) for nonproduction workers, including bonus and temporary pay.

Another report, from the Japan Iron and Steel Federation, shows the average monthly pay for 135,000 production workers in 55 member companies to be 32,722 yen ($91). In addition, each worker received bonuses averaging 8806 yen ($24.50) per month and welfare benefits costing 5900 yen ($16.30) per month.

From the two, we might say that the cash pay is somewhere between $97 and $115 per month. Actually, wages paid by the larger producers run higher than those in the smaller companies. With the average working time of 213 hr per month for production workers, the hourly rate would be 45.5¢ to 54¢. The normal work week is eight hr a day, six days a week.

In addition to the $16 per month of welfare benefits, companies maintain housing which can be rented for $1 or $2 per month, $6 for supervisors' houses. Also, clinics, hospitals, commissaries, cultural, sporting and recreational facilities and low-cost loans are provided. These things are hard to evaluate, but benefits are estimated to total about $40 a month. It might be safe to say that

This hot strip mill operates at the Mizue works of Nippon-Kokan K.K. (Japan Steel and Tube Corp.). It is a 68-in. semi-continuous unit.

total compensation is about 21 per cent of that in the U. S.

At present, wage differentials between jobs are not great. A man's rate depends more on his length of service than on his job, but there is evidence that this is changing. Also, wages in the large companies are on the rise. The average wage is said to have increased 43.3 per cent between 1955 and 1960, although steel prices have not changed much since 1955.

Bonuses depend on company profits. They may amount to 1.5 to 2 months' pay, twice a year. An interesting sidelight are the crowds to be found in the department stores right after bonus time. This is also gift-giving time, including gifts to supervisors.

Compensation includes paid vacations of 14 to 20 days, depending on the length of service.

The retirement age is 55, at which time a lump sum is given. There are no regular pensions. The retirement grant will vary with the length of service with the company. A month's pay for each year worked is typical. Incidentally, the work force could be increased easily, as needed, by raising the retirement age.

PRODUCTIVITY

Venturing into the risky field of productivity, we might take the Federation's figures for 1960, which show total employment of 277,198, average monthly hours of 209 and ingot production of 24,500 tons. This works out to 28.5 man-hours per ton. If technical and clerical workers are omitted, the figure is 24.4 man-hours per ton. This is high in comparison with the U. S. overall figures of 10.9 man-hours per ton. However, the Japanese figure apparently includes a number of metal-working plants.

If similar calculations are made for some of the larger integrated steel plants, figures of 9.8 to 16.4 man-hours per ingot ton are obtained. Reported figures show productivity increased 76.3 per cent between 1955 and 1960.

Japanese steelmakers realize their work forces are large, but reductions are difficult to make. Rather, they expect to man their expanded industry without a proportionate increase in manpower.

INDUSTRY ORGANIZATIONS

The Japan Iron and Steel Federation was established in 1948 to improve the country's iron and steel industry. Its committees prepare schedules for the importation of raw materials, production of steel and export of steel products. Work includes market research, foreign missions and study teams, industry problems, public relations, industry statistics, library reference, etc. The Federation is considering the establishment of a school to train technicians for the industry.

The Federation consists of 63 companies comprising 94 per cent of the steel-producing capacity of the country, as well as many foundries, forge shops and rerolling plants. It is supported by a levy on the production of the member companies.

The Iron and Steel Institute of Japan was founded in 1915 and now has about 7000 members of various grades. Its object is to study the techniques and problems of the iron and steel industry. Activities include a journal, miscellaneous books, meetings and research. It deals principally with metallurgical subjects and devotes scant attention to the engineering and equipment aspects of the industry. It is supported by individual members' dues and by sustaining company memberships.

PLANT DATA

The 13 plants visited represent a steel capacity of over 20,000,000 net tons a year, three quarters of the country's present total. Some details of the plants visited, as well as of other Japanese plants, are given in the following pages.

YAWATA IRON AND STEEL COMPANY, LTD.

This company is the largest steel producer in Asia. It was established in 1950 when the Japan Iron and Steel Co., Ltd., was broken up into several components. Actually, its inception dates back to 1896, when the Japanese government started to build an integrated steel plant at Yawata. By 1925 the plant had an annual capacity of 825,000 tons. In 1934, this government-owned property was merged with five privately-owned companies to form the Japan Iron and Steel Co., Ltd. Following the merger, the Yawata plant was expanded. Annual capacity grew to 2,620,000 tons.

In 1955, Hikari works was established, and now consists of two electric furnaces, a continuous casting unit, two rod mills and a hot extrusion press.

At a location, near Osaka, the company is building another new plant, Sakai works, on a site of 890 acres. The first facility there, just nearing completion, is a large section mill. By 1965, the plant is to consist of two 2000-ton blast furnaces, sintering equipment, three 88-ton oxygen furnaces, a slabbing mill and hot and cold strip mills. The estimate for this project is $180,000,000, which means about $128 per ton for the 1,400,000 tons of annual capacity.

The company is considering the construction of another large plant near Tokyo.

At present, steel producing is concentrated chiefly in the Yawata and Tobata plants, located close together on the northern tip of Kyushu island.

Yawata works—This plant has ten batteries of coke ovens, totaling 599 ovens, providing annual capacity for

2,725,000 tons of coke. There are two groups of four blast furnaces, with 18 ft-5 in. to 25 ft-3 in. hearth diameters. Two of the small furnaces are to be torn down and replaced by a large furnace. Present capacity totals about 3,000,000 tons of iron per year.

There are four separate open hearth shops containing 31 furnaces ranging in size from 66 to 165 tons and providing annual capacity for 4,400,000 tons of ingots. They operate on 50 to 53 per cent hot metal and turn out heats in about six hr, tap-to-tap. Fuel is coke-oven gas and oil, with consumption running 2,200,000 Btu per ton. Approximately 970 cu ft of oxygen is used per ton of ingots.

Two 66-ton oxygen converters offer capacity for another 850,000 tons of ingots per year. These vessels operate with 28 to 30 per cent scrap, turning out heats in 40 min, tap-to-tap. About 1760 cu ft of oxygen is used per ton of ingots. Lining life is said to be over 400 heats.

There are also four 22-ton electric furnaces, and a new 66-ton unit is being installed.

Ingots are rolled in five blooming mills, three of which have been recently remodeled. Two of these are followed by continuous billet mills.

A new 160-in. plate mill has a 2-high rougher and a 4-high finisher with attached edger. The 4-high stand is driven by two 5000-hp motors in a twin-drive arrangement. This unit has replaced three old plate mills. There is also a 2-high, single-stand 118-in. heavy plate mill.

Other rolling facilities include a rail mill, two heavy section mills (30 to 35 in.), two medium section mills (20 to 25 in.), a 13-in. light section mill and a 10-in. rod mill.

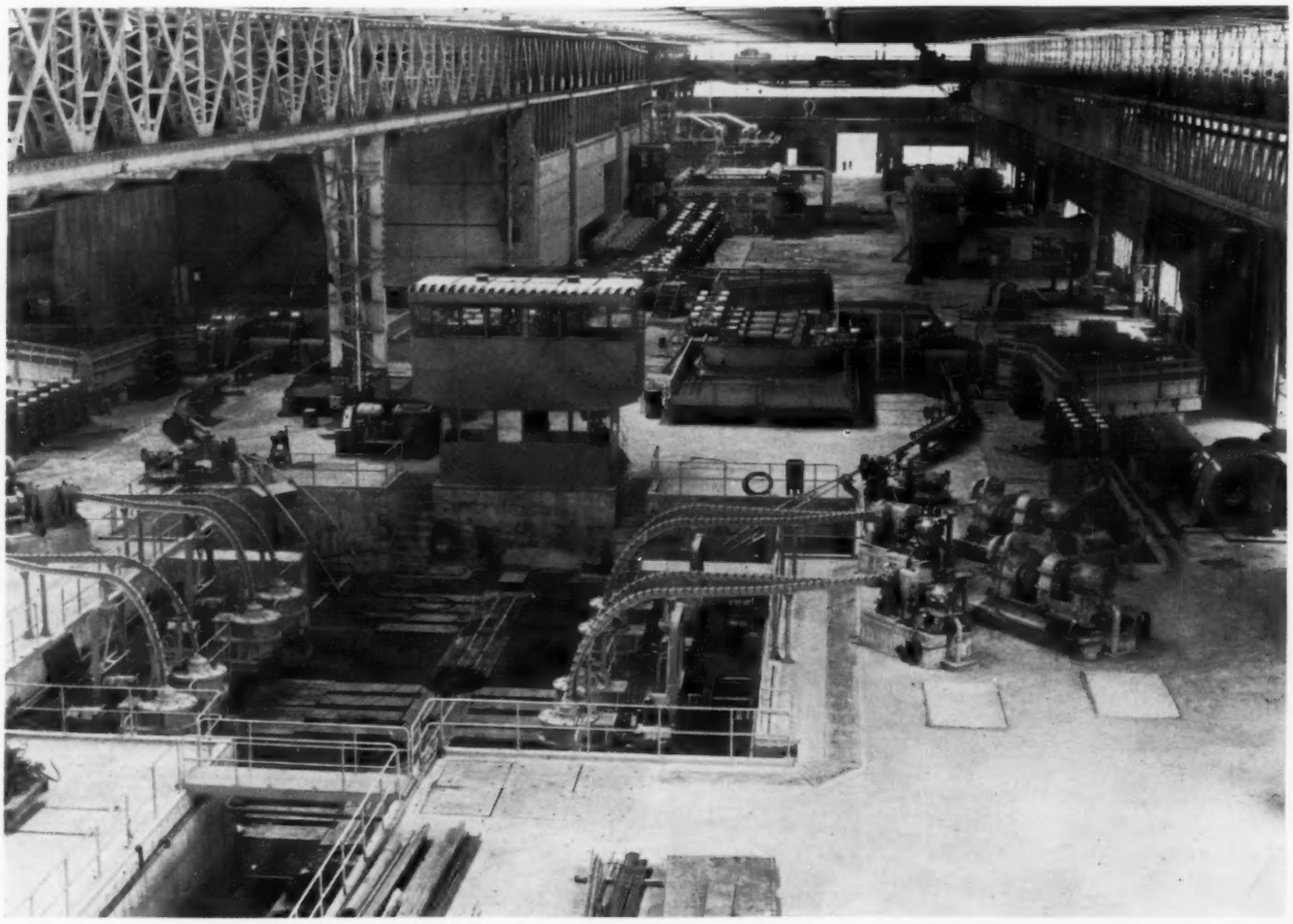
Silicon sheets are also rolled at Yawata on hand mills and on cluster strip mills. This department is being expanded.

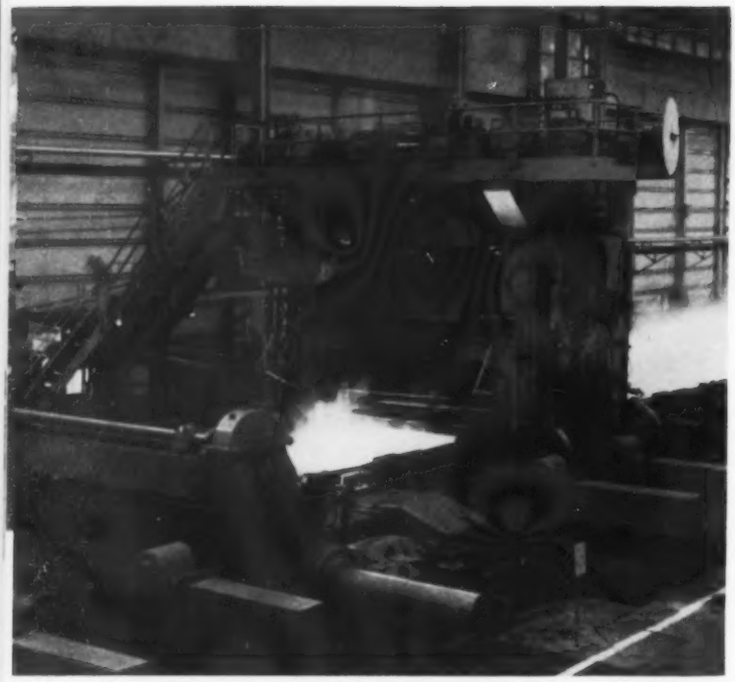
Tobata works—This plant now has 144 coke ovens of 692,000 tons annual capacity. Additional ovens now under construction will raise this to about 1,300,000 tons per year. Two blast furnaces of about 29-ft hearth diameter give a combined capacity of 1,500,000 tons of iron per year. A third furnace designed for 2400 tons per day is nearing completion. Three 77-ton oxygen converters, turning out heats in 40 min, tap-to-tap, provide an annual capacity of 2,000,000 tons of ingots, which are roughed down by a new 48 x 118-in. slabbing mill. Two 130-ton converters are under construction.

The Tobata slabbing mill is one of the few in Japan to have a continuous hot scarfing machine.

Tobata works is a flat-rolled facility, with a 43-in. continuous hot strip mill and an 80-in. semi-continuous mill. Three pickling lines, two tandem cold mills, a reversing cold mill and temper mills provide facilities for full finished sheet. Processing lines are available for galvanizing, bonderizing, continuous annealing, electrolytic tinning and hot-dip tinning. A new 6-stand, 56-in. tandem mill is under construction and processing equipment is being expanded. Plans call for aluminizing and thin tin plate in the near future.

Typical of the new mill installations is No. 4 rod mill of Kobe Steel Works, Ltd. It is the most recent rod mill installation in Japan.





This 160-in. plate finishing stand is driven by two 5000-hp reversing motors in twin-drive arrangement. The mill replaced three old plate mills at Yawata Iron and Steel Co.

Overall, Yawata Iron and Steel Co. now has annual capacities for 3,417,000 tons of coke, 4,500,000 tons of iron and 7,250,000 tons of ingots. Present plans will boost steel capacity to 10,000,000 tons of ingots by 1965. A 1970 capacity of 13,500,000 tons is in the planning stage.

Yawata also has a number of subsidiaries which produce seamless tube, electric weld pipe, spiral pipe, containers, welding electrodes, chemicals and miscellaneous metal products.

The company carries on extensive research programs through its research institute, employing about 700 people.

Total employment of the company is about 40,000 people. Against the present capacity, this would work out to 14.8 man-hours per ingot ton, overall.

FUJI IRON AND STEEL COMPANY, LTD.

Like Yawata, this company was formed in 1950 with the split up of Japan Iron and Steel Co., Ltd. It has four plants spread geographically over the country, and is at present the second largest steel producer in Japan.

Hirohata works—At Himeji, west of Kobe, is a modern integrated plant felt by many Japanese steel men to have the best location and the best layout of any in the country. The plant was originally constructed in the late 1930's. Over the past ten years, it has been modernized and expanded materially. It is a flat-rolled plant.

Good harbor facilities handle incoming raw materials. The harbor is to be deepened to take care of carriers up to 60,000 tons.

All ore is crushed and screened, with the coarse ore going to a bedding yard and the fines to the sinter plant. Coke is made in four batteries (75 ovens each) of by-product ovens totaling 1,125,000 tons annual capacity.

Three blast furnaces (25 ft, 25 ft-6 in. and 28-ft hearth diameters) provide a total rated capacity for 1,628,000 tons of iron per year but exceed this in production. The furnaces have carbon hearth walls and automatic stove changing. The large furnace has individual tuyère control of blast volume.

The furnaces operate with 30 per cent sinter, which will increase as new sintering facilities are completed. Iron content of the charge averages 61 per cent. Blast temperature runs 1670 to 1730 F. Coke rate averages 1200 lb per ton of iron. A fourth large furnace is planned.

Seven 220-ton tilting open hearth furnaces give a total annual capacity of 1,650,000 tons of steel. They are fired with heavy oil and coke-oven gas, and report fuel consumption of 1,600,000 Btu per ton. About 65 per cent hot metal is used. Heat time is about five hr, tap-to-tap. Oxygen consumption runs 1050 cu ft per ton.

There are also two 66-ton top-blown oxygen converters, which are rated at 800,000 tons per year but are producing beyond that rate. These operate with 75 per cent or more hot metal and turn out heats in 35 min, tap-to-tap. Oxygen use is 1600 cu ft per ton. Another converter is planned.

A 55-ton arc furnace is to be put in.

Steel is poured into ingots of 8 to 20 tons weight, which are heated in 27 modern recuperative soaking pits fired with mixed coke-oven and blast furnace gas, and then broken down by a 44-in. blooming mill or a new 45 x 90-in. universal slabbing mill.

Secondary mills include a 160-in., 4-high heavy plate mill and an 86-in. semi-continuous hot strip mill. The plate mill is rated at 725,000 tons a year. The hot strip mill, originally installed in 1939, has a 2-high scalebreaker, a 4-high, 40 and 52 x 120-in. reversing rougher and six 4-high, 37 and 52 x 86-in. finishing stands. This unit is rated at 1,320,000 tons per year.

Finishing equipment includes a 5-stand, 56-in. cold mill, an 80-in. reversing cold mill, temper mills and facilities for pickling, annealing, tinning and galvanizing.

A wide-flange beam mill is under construction.

Employees at Hirohata number about 11,200, including 1000 staff people. This works out to 11.5 man-hours per ingot ton. Plant area is 1000 acres.

Muroran works—This unit of Fuji Iron and Steel was started in 1909. It is located on the northern island of Hokkaido, where it is the only integrated plant. It has 219 coke ovens of 765,000 tons annual capacity and four blast furnaces of 1,900,000 tons annual capacity. The newest furnace, of 27-ft hearth diameter, is rated at 1870 tons per day. It has carbon hearth walls and automatic stove changing. No. 3 furnace is to be rebuilt for high top pressure. The furnaces operate with 60 per cent sinter, supplied by three old lines and one new one.

Steel is made in six 220-ton open hearth furnaces, one stationary and five of tilting design. They have a total capacity of 1,340,000 tons per year. They operate with a charge of 60 to 75 per cent hot metal and turn out heats in 5½ hr, tap-to-tap. Coke-oven gas and oil are burned. About 870 cu ft of oxygen is used per ton of steel made. Ingots usually range 6 to 15 tons in weight.

Two 77-ton oxygen converters were put into operation recently. They will add capacity of 924,000 tons of steel a year.

Ingots are roughed down in a 42-in. blooming mill followed by a continuous billet mill, or in a 46 x 115-in. high-lift slabbing mill.

Yawata works of Yawata Iron and Steel Co. is the largest steel plant in Asia. In layout, it is actually a group of producing units rather than a single plant.

In 1957, a 56-in. semi-continuous hot strip mill went into operation. It is rated at 1,320,000 tons a year. A cold mill is to be installed.

There are also a medium section mill and a rebuilt 2-strand rod mill.

The Muroran plant is on a site of 1080 acres. It has about 8800 employees indicating a figure of 9.8 man-hours per ingot ton.

Fuji operates two other plants which were not visited. The Kamaishi works is of historical significance, as it was here that the first blast furnace in Japan was built in 1887. At present, this plant has the following facilities:

	Rated capacity, tons per year
A total of 110 by-product coke ovens	522,000
One blast furnace, 22 ft-3 in. hearth One blast furnace, 23 ft-10 in. hearth	780,000
Four tilting open hearths, 155 ton One tilting open hearth, 220 ton	922,000

Rolling mills include a 44-in. blooming mill, and heavy, medium and light section mills. A rod mill has just been completed.

Kawasaki works has a light section mill, a hoop mill and a cold forming mill.

Overall, Fuji Iron and Steel now has annual capacities of 4,300,000 tons of iron and 5,451,000 tons of steel ingots.

A wholly-owned subsidiary, Tokai Iron and Steel Co., Ltd., is building a new integrated plant near Nagoya. A cold strip mill has just gone into operation there. By 1963 this plant will have a 2200-ton blast furnace, two 132-ton oxygen converters, a slabbing mill and a 68-in. continuous hot strip mill. Plans call for an ultimate capacity of 5,000,000 tons a year, with four blast furnaces, five oxygen converters, three blooming mills, etc.

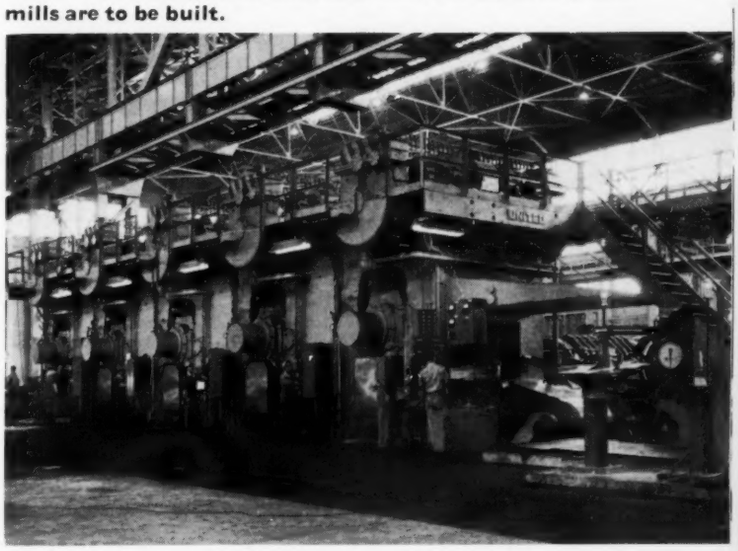
It is understood that Fuji is also contemplating other new plants in the Tokyo and Beppu areas.

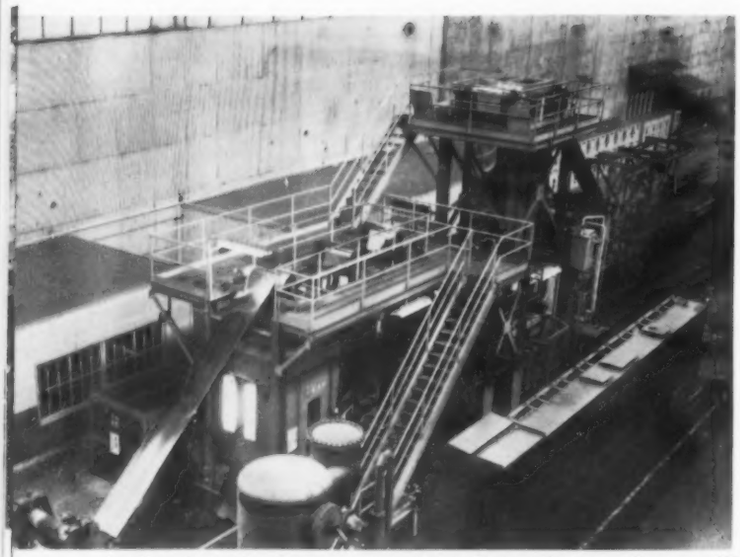
Fuji now has about 620 people working in research. This will grow to 1000 when a new research center is completed.

NIPPON-KOKAN K.K.

This company, also known as Japan Steel and Tube

This 56-in., 5-stand tandem cold mill is installed in Hirohata works of Fuji Iron and Steel Co. Numerous new cold mills are to be built.





Indicating the larger part that flat-rolled products will play are modern continuous processing lines, such as this electrotinning line at Fuji's Hirohata works.

Corp., produces iron and steel, ferroalloys and refractories, and builds ships and marine machinery. It is currently the third largest steel producer in Japan. Steel producing is centered chiefly in three plants near Tokyo, rated in the Federation directory as follows:

	Net tons per year		
	Coke	*Iron*	*Steel*
Kawasaki plant	988,000	1,560,000	1,380,000
Mizue plant	...	...	890,000
Tsurumi plant	...	665,000	560,000
Total	988,000	2,225,000	2,830,000

Tubular products are a specialty of Nippon-Kokan K.K. This seamless tube mill is one of three in the company's Kawasaki works.

Actually, these figures are exceeded in practice, with Kawasaki reaching 2,000,000 tons of iron and 1,660,000 tons of ingots, Mizue going to 940,000 tons of ingots and Tsurumi reaching 790,000 tons of ingots. This would bring Nippon-Kokan's actual annual ingot capacity to 3,390,000 tons.

Kawasaki plant—Originally established in 1912 for tube production, this plant has been modernized and expanded, it now specializes in tubular and structural products. It has four batteries totaling 229 by-product ovens. Four blast furnaces (two of 22 ft-8 in., one of 23 ft-6 in. and one 23 ft-8 in. hearth diameters) produce 173,000 tons of iron per month, considerably more than the rated capacity.

Approximately 78 per cent of the ore used in the plant is imported. Ocean carriers are unloaded on a small island near the plant. Ore is crushed, screened and bedded, then reclaimed and moved by barges to the furnace area. Fines go to the sintering plant where they are made into self-fluxing sinter. About 47 per cent of the blast furnace charge, which averages 59 per cent iron, is sinter. Coke consumption is 1190 lb per ton of iron.

Steel is made in three 132-ton and three 66-ton open hearth furnaces and two 46-ton oxygen converters. These units produce 78,000 tons of open hearth steel and 60,000 tons of oxygen steel per month, again considerably more than the rated capacities. The larger furnaces turn out 4.7 heats per day; the smaller furnaces, 5.7 heats per day. The furnaces are fired with coke-oven gas and oil, and use 650 to 950 cu ft of oxygen per ton of ingots.

Rolling facilities include a 3-stand heavy section mill (which rolls blooms, billets, slabs and beam blanks), another 3-stand heavy section mill, a 5-stand medium section mill, two light section mills and a continuous hoop mill.

Three seamless tube mills cover a product range from 2 to 16 in. in diameter. Two electric weld units are now operating and another larger one is nearing completion, affording a diameter range of 2 to 16 in. A continuous butt weld mill makes pipe of ½ to 2 in. in diameter.

Mizue works—Adjacent to the Kawasaki works is a new project first operated in 1959. One 29 ft-6 in. blast furnace is under construction and two more are planned. Coke ovens will be built in the coming years. About 78,000 tons of steel per month is made in two 66-ton oxygen converters. Iron is brought from the Kawasaki plant. A third converter is under construction. These units turn out 80-ton heats in 40 min, tap-to-tap, using about 1770 cu ft of oxygen per ingot ton.

Mizue is a flat-rolled plant. There is a 46 x 114-in. slabbing mill and a 68-in. semi-continuous hot strip mill. At present, there is a reversing cold mill and a 6000-fpm tandem mill, which has been recently completed. Plans for this plant over the next few years include coke ovens, a sintering plant, two more blast furnaces, a third oxygen converter, continuous lines for galvanizing, annealing and tinning and other finishing facilities.

Tsurumi works—This unit has no coke ovens, and purchases its requirements from the Tokyo Gas Co. There are two blast furnaces, one is a small unit of 17 ft-9 in. hearth diameter, the other has a 24 ft-3 in. diameter. The burden includes 40 per cent sinter.

These units are to be remodeled and enlarged. At present, the blast is enriched to bring oxygen content up to 23 per cent.

Steel is made in four 85-ton stationary open hearths and one 176-ton tilting unit. Operating on 60 per cent hot metal, these furnaces turn out heats in 3½ to to 4½ hr, using 735 cu ft of oxygen per ton. Only oil is burned. Roof life is said to be 400 heats on the small furnaces, 250 heats on the large furnace.

Ingots are bottom poured in this plant, then rolled on a modern heavy plate mill consisting of a 2-high vertical scalebreaker, a 2-high, 130-in. rougher and a 4-high, 120-in. finishing stand. There is also a 3-high, 83-in. plate mill.

Plate rolled at Tsurumi works goes to the company's adjacent shipyards or to a welded pipe mill with U and O presses and welding facilities. This unit makes welded pipe 14 to 34 in. in diameter.

Larger sizes, up to 100 in. diameter, are made at the shipyard by rolling the plate into cylinders and welding by hand. Considerable marine machinery is also manufactured at the shipyard.

Employees for the three steel plants are reported at about 22,500. This would indicate about 19.6 man-hours per ingot ton on the rated capacity, but only 16.4 on the actual production rate.

Nippon-Kokan is planning to build a fourth large integrated steel plant near Nagoya.

KAWASAKI STEEL CORPORATION

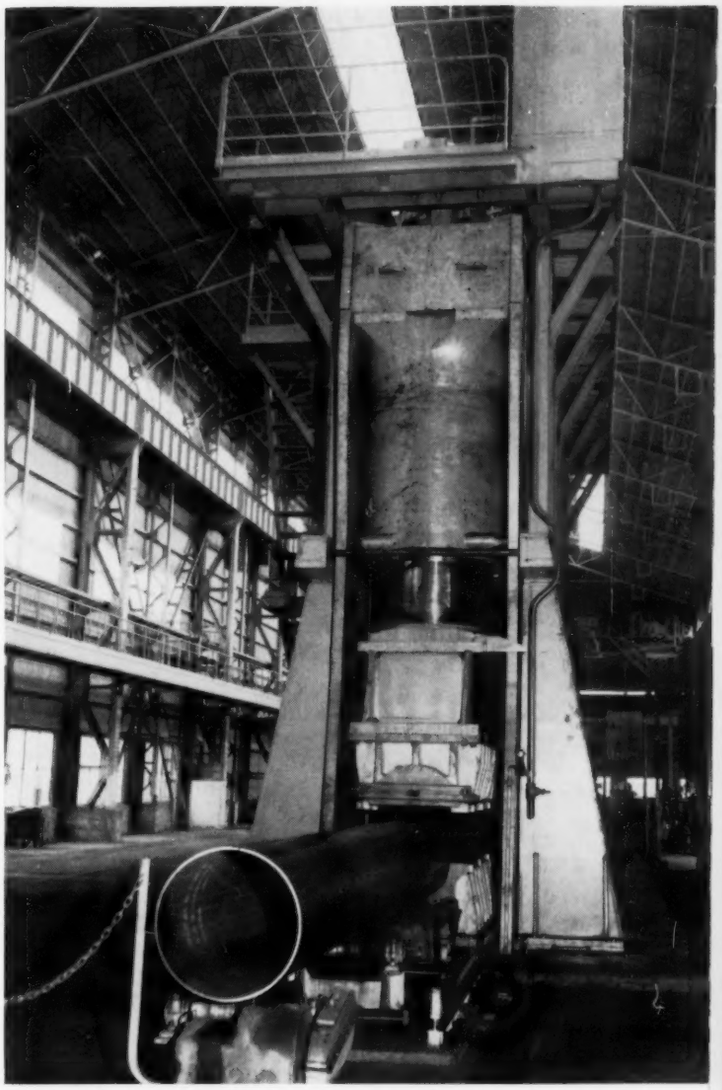
This corporation was formed in 1950 by the separation of the five steel-producing plants of Kawasaki Heavy Industries, Ltd., from the parent company. These plants are located at Fukiai, Hyogo, Kuji, Nishinomiya and Chita. They are small and not particularly modern or efficient.

Chiba works—Early in 1951, construction was started on Chiba works, a fully-integrated plant on an 800-acre site reclaimed from Tokyo Bay, about 30 miles from Tokyo. By 1954 one blast furnace, three open hearth furnaces and a slabbing mill were completed. A second blast furnace and hot and cold strip mills were completed in 1958, and a year later, the third blast furnace and three more open hearth furnaces were added. More expansion is under way.

At present, there are three blast furnaces operating (21 ft-6 in. to 29 ft-10 in. hearth diameters) with an annual capacity of 1,513,000 tons. The fourth furnace is almost ready and a fifth is planned. Coke is supplied by three batteries of by-product coke ovens, with a fourth battery under construction and a fifth planned.

Iron ore (more than 85 per cent imported) and coal (54 per cent imported) are unloaded directly from ocean carriers. Ore is crushed and screened, with large sizes going to a bedding area and small sizes to pelletizing units. About 30 per cent of the blast furnace burden is pelletized and runs 60 per cent Fe. Expansion of pelletizing facilities will put the burden up to 65 to 70 per cent pellets.

Operating on a charge of 60 per cent hot metal and 40 per cent scrap, the six 180-ton open hearth furnaces produce heats in about four hr, tap-to-tap, with fuel (oil and coke-oven gas) consumption of 1,300,000 Btu per ton. Approximately 1440 cu ft of oxygen per net ton of ingots is used through door lances. Roof life runs 250 to 300 heats. Actual capacity is approximately 2,200,000 tons per year.



Welded line pipe 14 to 34 in. in diameter is made at the Tsurumi works of Nippon-Kokan. Plate comes from a 120-in. mill in the same plant.

Now under construction is a basic oxygen converter shop with two 165-ton vessels. This will add 1,980,000 tons per year of steelmaking capacity.

Rolling facilities now operating include a slabbing mill, a 166-in. plate mill, a 56-in. semi-continuous hot strip mill and a 5-stand, 56-in. cold mill. Now under construction is a new universal slabbing mill, and an 80-in. hot strip mill is planned.

The Chiba works also has facilities for wire drawing and the production of wire rope and welding rod. A continuous galvanizing line is under construction. Plans are being made for a 6-stand tandem cold mill and tin-plate facilities.

The layout of Chiba works is very compact. When the oxygen steel plant goes into operation, there will be an integrated annual capacity of almost 4,200,000 tons on an 800-acre site—less than 200 acres per million tons.

At present, there are 11,600 employees at Chiba works, which would indicate about 13 man-hours per ingot ton. Employees belong to an independent union and are said to receive wages slightly higher than the average of the industry.

This view shows part of Nippon-Kokan's Tsurumi shipyard, adjacent to the Tsurumi steel plant, which supplies plates for shipbuilding.

It was stated that the cost of the Chiba plant, including the facilities now planned, will total $360,000,000, or approximately $90 per ton of annual capacity.

Fukiai works—This plant began operations in 1918 and in 1924 produced Japan's first commercial steel sheets. It now has ten small open hearths of 460,000 tons annual capacity, heavy plate mills and sheet mills. A cluster mill is used for cold rolling silicon steel strip. A wide-flange beam mill is under construction.

Hyogo works—This unit has two 25-ton open hearth furnaces and two arc furnaces with a combined annual capacity of 125,000 tons. Two small merchant mills, forging presses, cupolas and foundry equipment are available. Two vacuum casting units have been installed. This plant produces steel, alloy and iron castings, steel forgings and steel bars for rolling stock, machinery, construction work, etc.

Nishinomiya works—Plant has a capacity of 120,000 tons of steel a year from five arc furnaces. Rolling facilities include a small blooming mill, a plate mill, two small hoop mills and four fusion-welding pipe lines. There are also four induction furnaces for foundry use.

Chita works—Foundry equipment and a small rolling mill are operated at Chita works. Castings produced here include rolls and ingot molds. A spiral-weld pipe mill is being installed. Annual capacity is rated at 98,000 tons.

Kuji works—This is essentially a direct reduction plant with two 70-ton-per-day rotary kilns and two 6-ton-per-day kilns. It produces open hearth charge material from iron sand.

Kawasaki Steel Corp. also operates a plant for the production of steel drums.

At the moment, Kawasaki is the fourth largest producer, with total annual capacities of 1,570,000 tons of iron and 2,994,000 tons of ingots. Both figures will increase soon. Another new plant is being considered.

SUMITOMO METAL INDUSTRIES, LTD.

Sumitomo, the result of a 1953 merger, is the fifth largest steel producer in Japan. It operates five plants: Wakayama works, Kokura works, Amagasaki tube works, Osaka works and Suita works. At present they provide capacities for 1,223,000 tons of iron and 2,420,000 tons of steel per year. Only the first two plants were visited.

Wakayama works—This plant, located south of Osaka, is undergoing a general rebuild. Two batteries, totaling 70 ovens, coke 1520 tons of coal per day and produce about 1100 tons of coke.

With the exception of some domestic iron sand and pyrite cinder, all ores (about 90 per cent) and 50 per cent of the coal are imported. Raw materials arrive principally by sea and are stored in yards that can accommodate 190,000 tons of ore, 90,000 tons of sinter and 110,000 tons of coal. They are handled

entirely by belt conveyors. One blast furnace (26 ft-11 in. hearth diameter) is rated at 1320 tons per day, but produces about 1540 tons a day; a second furnace, somewhat larger, is under construction and the third is planned. Six furnaces are the ultimate goal for this plant. The existing furnace has carbon hearth walls and automatic stove changing.

Iron ore is carefully sized and blended. The furnace charge is 65 per cent sinter, and is said to average 62 per cent iron. Ore usage of 3060 lb and a coke rate of 1100 lb per ton of iron are reported.

Steel is made in two 110-ton and two 220-ton open hearth furnaces, with an annual capacity of 990,000 tons. The furnaces are fired with coke-oven gas and heavy oil. Charges at present consist of 50 per cent hot metal, 10 to 20 per cent cold pig and 30 to 40 per cent scrap. About 970 cu ft of oxygen is used per ton of steel. Heat times, tap-to-tap, average 4½ hr for the smaller furnaces, 5½ hr for the larger furnaces. At present, ingots range eight to nine tons, but 20-ton ingots are to come.

Two 88-ton oxygen converters will go into production in the next two years, and a third unit is planned for 1965.

Ingots are roughed down into blooms, slabs and tube rounds in a 2-stand tandem blooming mill. The first stand is a 48-in. high-lift unit, the second a 36-in. mill equipped with preset control. This mill is served by 16 recuperative pits fired with mixed gas. A scarfing machine is being installed.

There is also a 15-stand continuous narrow strip and hoop mill built in 1953.

Tube production is the big item at the Wakayama plant. A plug-type seamless mill covers sizes from 4½ to 14 in. This mill has been rebuilt with two piercers. A resistance electric weld mill, newly completed, produces sizes of 4 to 16 in. A spiral weld pipe mill handles diameters up to 50 in. There are also two small electric weld mills for sizes up to 2 and 4 in., respectively.

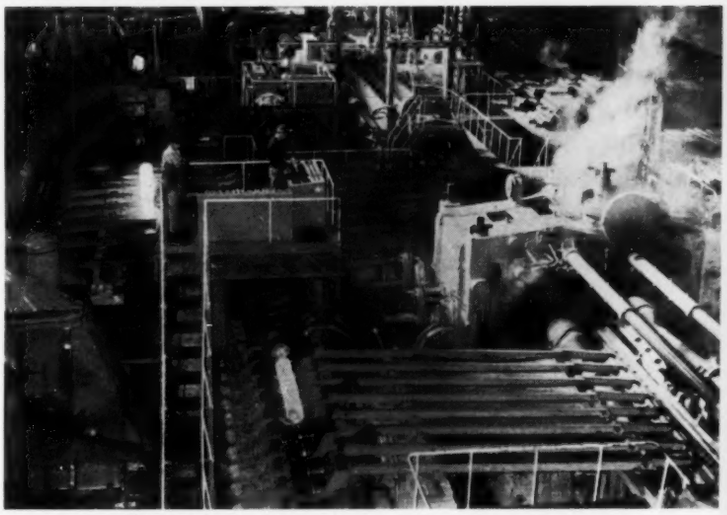
Under construction is an 80-in. semi-continuous hot strip mill, a tandem cold mill and auxiliary finishing equipment.

Future plans call for a plate mill, a unit for line pipe, a continuous butt weld mill and additional electric weld pipe mills. Annual capacity is to be 2,750,000 tons in 1965 and 5,500,000 tons eventually. The layout of the future facilities is well planned and fronts on a harbor which is being enlarged to take 60,000-ton vessels.

Kokura works—This unit of Sumitomo is located near Yawata, on the southern island, Kyushu. Two blast furnaces (18 ft-4 in. and 19 ft-8 in. hearth diameters) produce 647,000 tons of iron per year. At present, iron ore is trucked from a nearby port, but an unloading wharf is being built to accommodate some of the smaller carriers. All coke is purchased. The blast furnace charge, which averages 60 per cent iron, contains 55 per cent sinter and five to seven per cent pellets. Coke consumption averages 1188 lb per net ton of iron. The small furnace is to be rebuilt.

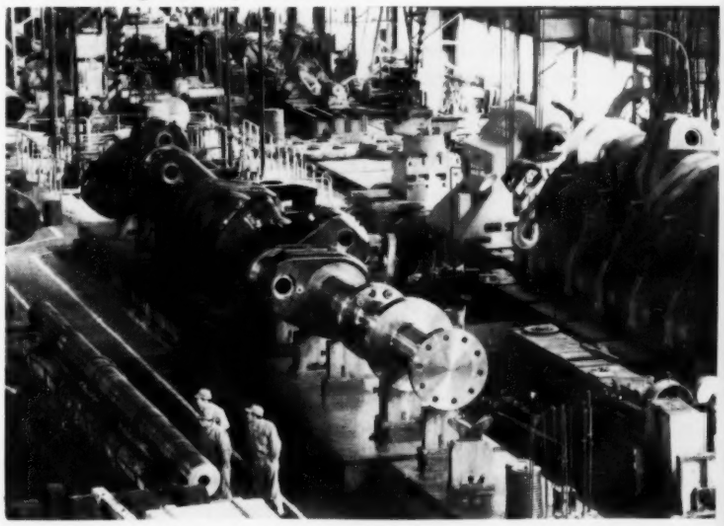
Steel is made in four 55-ton open hearth furnaces and two 55-ton oxygen converters. The open hearths operate with 57 to 60 per cent hot metal, using 14 gal of fuel oil and 1120 cu ft of oxygen per ton. They

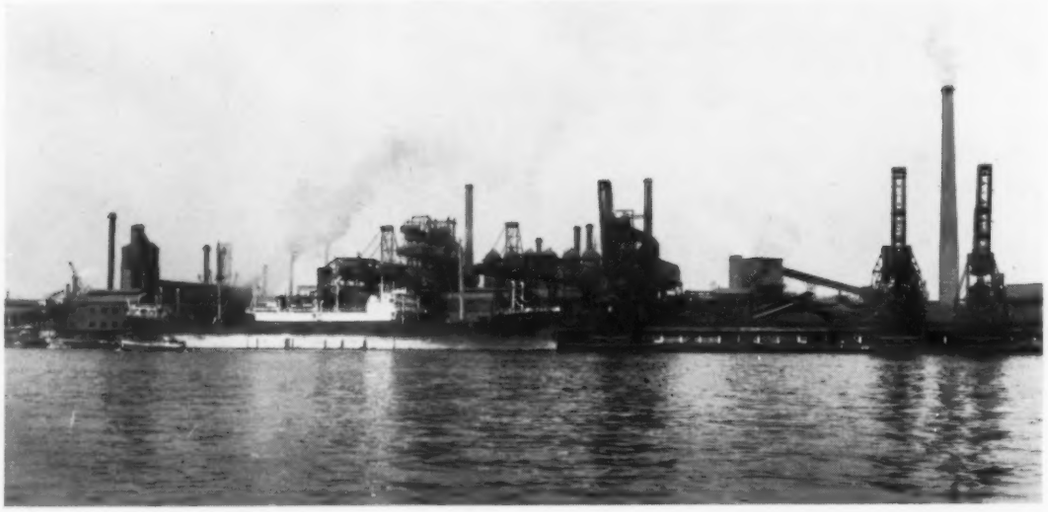
Chiba works of Kawasaki Steel Corp. has operated this 56-in. semi-continuous hot strip mill for some years. Plans call for a new 80-in. hot mill.



Sumitomo Metal Industries, Ltd., is an important producer of tubular goods. This seamless tube mill is in the Wakayama works, where tube and pipe facilities have been modernized and expanded.

In addition to being a steel producer, Kobe Steel Works, Ltd., is an important manufacturer of industrial and marine machinery, tools, etc. This view shows crankshafts for diesel engines in production.





General view of the dock facilities serving the Nakayama Steel Works, Ltd. Started in 1923, this family-controlled company has developed into an integrated unit. A reversing hot strip mill is to be put in.

produced 490,000 tons in 1960 at a rate of 21 tons per hr. The oxygen converters went into operation early in 1961, with a rated annual capacity of 670,000 tons. They are turning out heats in 40 min, tap-to-tap, using 1700 to 1920 cu ft of oxygen per ton. Ingots are bottom-poured in small sizes, running 200 to 1400 lb. There is no blooming mill.

Rolling facilities include a 3-stand, 22-in. medium section mill, a 6-stand, 12-in. light section mill, an old 13-stand, 12-in. rod mill and a modern continuous rod mill that turns out about 25,000 tons per month. A new rod mill is planned.

Steel Tube works—At Amagasaki, west of Osaka, there is a 50-ton arc furnace, six small arc furnaces and two induction furnaces, totaling a capacity of 103,000 tons per year.

Rolling facilities include a 34-in. bloomer and a 30-in. bar mill, used principally to produce tube rounds. Tubes are made on a seamless mill, an electric weld mill and two extrusion presses. Facilities include draw benches, tube reducers, forging presses, etc.

Products from this plant are principally tubular goods of 5½-in. diameter and smaller, and pressure vessels of various kinds.

Osaka works—This plant has a 66-ton acid open hearth furnace, five arc furnaces of 7 to 28 tons capacity and two induction furnaces, giving an annual capacity of 215,000 tons of steel. An 88-ton arc furnace is nearing completion. A vacuum casting unit and a 2-strand continuous casting machine are installed. Rolling is done on two merchant mills. There are also five mills for the production of wheels, tires and springs. Plant facilities also include many forging presses and hammers.

This plant turns out parts for rolling stock, as well as other castings and forgings.

Suita works—This is a small shop with three small induction furnaces. It produces permanent magnets, nickel alloys and metal powder products.

KOBE STEEL WORKS, LTD.

This company operates a number of plants grouped near Kobe. It produces wire rod, steel bars, structurals, sheet plate, steel castings and forgings, iron castings, nonferrous metals (aluminum, copper, magnesium, titanium), industrial machinery and tools, oxygen plants, etc. The company has many license agreements with American and European manufacturers. Company business is approximately 54 per cent iron and steel products, 31 per cent machinery and 15 per cent nonferrous metals.

Kobe works—This unit is composed of four plants. The Nadahama plant has a 19 ft-8 in. blast furnace rated at 660 tons per day but producing 1100 tons. It operates on 45 per cent sinter. The charge runs 60 per cent iron. Coke consumption is 1100 lb per ton. All coke is purchased. Blast temperature averages about 1600 F.

A new 1000-ton-per-day blast furnace is under construction and two 66-ton oxygen converters are just about ready to go into operation.

The Nadahama plant has a blooming mill under construction. There are two rod mills in operation.

The adjacent Wakinohama plant has eight 50-ton open hearth furnaces, one 28-ton open hearth and a 66-ton arc furnace, providing an annual capacity of 885,000 tons. There is a 36-in. bloomer in line with a 2-stand, 3-high billet mill. There are also a 30-in. bar mill, a 13-in. bar mill and two rod mills.

Iwaya plant has iron and steel foundries, forge shops and machine shops. Four arc furnaces give a capacity

In addition to making steel and rolling plate, Japan Steel Works, Ltd., has extensive foundry, forge and machine facilities. It produces rolls, industrial machinery and some armament.

This view emphasizes the close link between Japan's heavy industry and the sea. Shown here is Muroran harbor and the plant of Japan Steel Works, Ltd. The Muroran works of Fuji Iron and Steel Co. is nearby.

of 70,000 tons of steel per year.

Yamata plant is devoted to the production of welding rod.

The company also operates the Takasago works with open hearth and electric furnace capacity of 278,000 tons a year. Products are principally forgings and castings.

There is also another welding rod plant (Hidaka), a ferroalloy plant (Kochi) and an extrusion plant (Chofu-Kita).

NAKAYAMA STEEL WORKS, LTD.

This is essentially a family-owned company that entered the steel business in 1923 and is now operating an integrated plant at Osaka and a small plant at Nagoya.

The Funamachi plant at Osaka has 103 by-product coke ovens of 414,000 tons annual capacity, and two blast furnaces (19 ft and 19 ft-8 in. hearth diameters) totaling 543,000 tons annual capacity.

Steel is made in six 80-ton and one 132-ton open hearth furnaces, and in three electric furnaces of 8, 10 and 40-ton capacity. These facilities provide an annual capacity of about 880,000 tons of ingots.

Steel is cast into ingots weighing 220 lb to 6600 lb. There is no blooming mill.

There are two single-stand, 3-high plate mills, 79 and 90 in. wide, two medium section mills, a light section mill, a rod mill and hot sheet mills.

At present a 4-high reversing cold mill and a cluster mill are cold-reducing coils purchased from the outside. A 39-in. hot reversing strip mill is under construction. Galvanizing and corrugating facilities are also available.

This plant showed unusually good housekeeping.

JAPAN STEEL WORKS, LTD

This company's principal plant is at Muroran, on the northern island, Hokkaido. It began in 1907 as an armament plant. At present there are two 88-ton basic open hearth furnaces producing 15,400 tons per month, two 77-ton acid open hearth furnaces turning out 7700 tons per month and two electric arc and three small induction furnaces producing 3300 tons a month. A new 80-ton top-charge arc furnace is going in. Three vacuum-pour units are installed.

There are no blast furnaces, and the basic open hearths operate on a charge of 75 per cent scrap and 25 per cent cold pig iron obtained from the nearby Muroran works of Fuji Iron and Steel Co. They are fired with straight heavy oil and turn out heats in five hr. Little oxygen is used.

Rolling facilities include a 4-high, 205-in. reversing plate mill driven by a steam engine. It is of German design and was installed in 1941. There are also a 3-high, 79-in. plate mill and a small reclaiming mill that rolls rounds up to about ¾-in. diameter from plate trimmings.

The plant also has seven hydraulic forging presses, six forging hammers, iron and steel foundries and some good machine ships.

Products include rotors, shafts, railroad axles, industrial machinery, etc. Cast steel rolls are made under license from an American company. Forged steel rolls are also produced. Some military equipment is also made here.

The company also operates a small plant at Hiroshima, where there are three small arc furnaces, a foundry and forging hammers. There are also machine shops at Yokohama and Musashi. ▲

Natural Gas Injection Into the Blast Furnace at Lone Star Steel Co.

by FRED W. FARMER, Combustion Engineer

and J. C. MORELAND, Junior Combustion Engineer, Lone Star Steel Co., Lone Star, Texas

. . . numerous changes in blast furnace operational procedure are desirable with gas injection . . . with natural gas injection the coke rate must be reduced by an amount related to the carbon content of the injected gas; the reduced coke rate permits smooth furnace operation at higher hot-blast temperatures; and the higher hot-blast temperatures increase furnace production . . .

LONE Star Steel Co. is located in the northeast corner of Texas within overnight trucking distance of 75 per cent of the country's oil and gas production. The plant is completely integrated, and produces oil field tubular goods and cast-iron pressure pipe.

The blast furnace at Lone Star has 18 tuyères, a 27-ft hearth and a working volume of 44,300 cu ft. The normal wind rate is 89,000 scfm. Furnace dimensions are shown in Figure 1.

The furnace is blown by a centrifugal blower rated at 100,000 scfm at 30 psig. The blower is driven by a 11,280-hp steam turbine using 400-psig steam at 750 F.

Blast air is heated by three stoves of conventional design. They are fired with blast furnace gas and have approximately 85 ft of multihole checkers. The checkers have an average volume of 14,700 cu ft and a heating surface of approximately 223,000 sq ft. Table I is a tabulation of stove dimensions. Chromel alumel thermocouples are installed in the domes and waste gas flues, and the temperatures are recorded on a multipoint strip chart recorder. Hydraulic fuel-air ratio controllers are used to proportion combustion air flow to fuel gas flow.

BURDEN

The furnace operates with native east Texas limonite and siderite ores that are mined within ten miles of the plant. The ore is beneficiated by crushing, washing and calcining. After beneficiation the ores average 50

Figure 1 — The main furnace dimensions are illustrated.

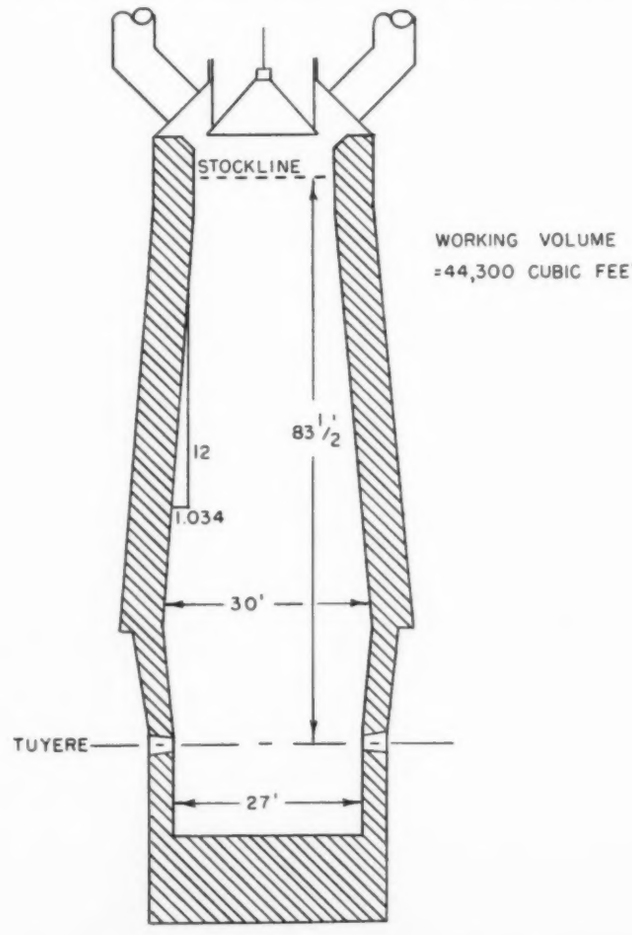


TABLE I
Blast Furnace Stove Dimensions

Stove	Multihole checkers		Basket weave checkers		Brick volume, Cu ft	Heating surface, sq ft	Ratio, heating surface to volume
	Ft	Size, in.	Ft	Size, in.			
1	75	1½ diameter	15	3½ x 3½	16,070	265,251	16.51 to 1
2	85	2 x 2	5	3 x 3	14,104	197,500	14.00 to 1
3	85	2 x 2	5	3 x 3	14,712	206,468	14.00 to 1

per cent Fe and 15 per cent SiO_2. The furnace burden is not sized, and bedding and blending facilities are not available. Approximately 30 per cent of the Fe charged is in the form of sinter and 10 per cent in the form of mill scrap. To control furnace top temperature, water is added to the burden in the skip cars. Coke is produced at the plant site from Oklahoma coal in by-product coke ovens.

FURNACE PRODUCT

The furnace is cast four times each day. Furnace product is open hearth hot metal averaging 1.25 to 1.50 per cent silicon and 0.030 per cent sulphur. Due to the possibility of wide fluctuations in ore analyses, the iron is hotter than that normally produced for open hearth use. The slag monkey is usually opened 2 or 2½ hr after closure of the tap hole. Slag is cast into pits where it is quenched by water sprays. The cooled slag is excavated, crushed and screened for concrete aggregate.

FURNACE OPERATION PRIOR TO GAS INJECTION

The furnace has always operated smoothly. It is seldom necessary to check wind to move the furnace. The following tabulation indicates average operation for a five-month period prior to natural gas injection: daily production, tons hot metal, 1053; coke rate, lb per ton hot metal, 2028; slag rate, lb per ton hot metal, 1500; hot blast, temperature, 1060; per cent Fe in ore, 49.78.

GAS INJECTION HISTORY

High-pressure natural gas has always been economically available at the plant site. The cost of carbon in natural gas is approximately one half the cost of carbon in $20 coke. During 1953 consideration was given to replacing a portion of the carbon normally supplied in the metallurgical coke with natural gas. The first experiments were conducted by injecting natural gas into one tuyère, and since that time several other preliminary tests have been completed. The test results indicated that gas could be successfully introduced into the hot-blast stream. It was observed that with gas injection the tuyères had a cold cloudy appearance and that tuyère cooling water discharge temperature decreased when gas was injected. A partial obstruction or hood would develop in the tuyère opening after gas injection had been continuous for one or two hr. The preliminary tests indicated the following:

1. Natural gas can be introduced into the furnace by means of pipes inserted through the caps.
2. Natural gas had a cooling effect on the area surrounding the tuyères.
3. To be successful, gas injection must be made into all of the tuyères. It is essential that the cooling effect of gas injection be distributed throughout the entire hearth area, where it can be compensated for by increased blast heat.

In the fall of 1959 results of the excellent work

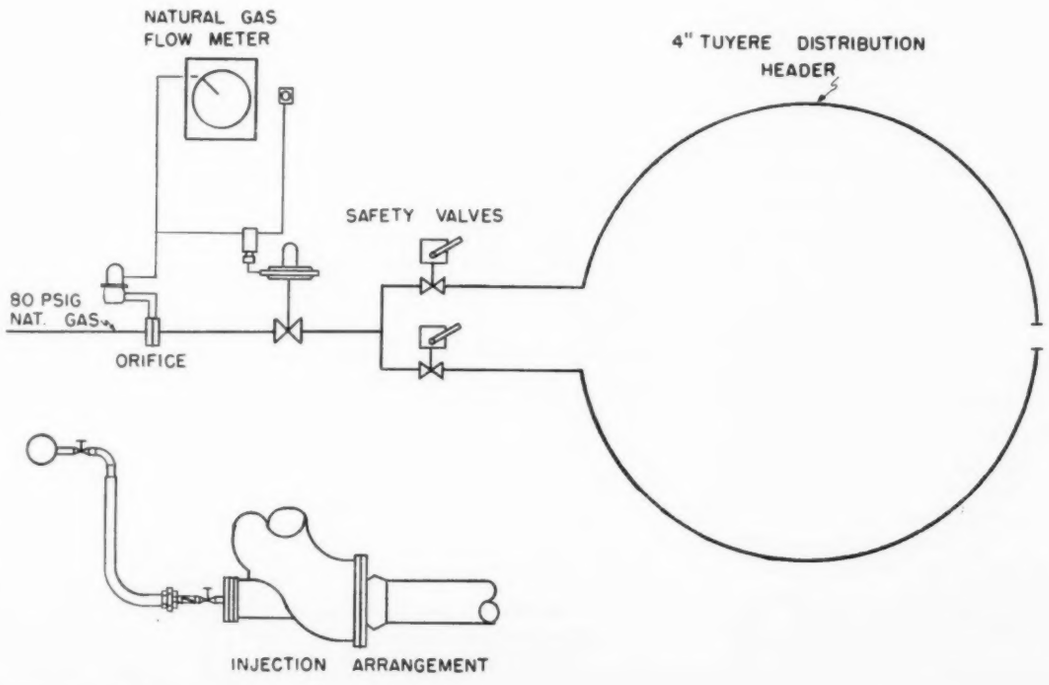


Figure 2 — Schematic layout of the piping illustrates the control and safety features used.

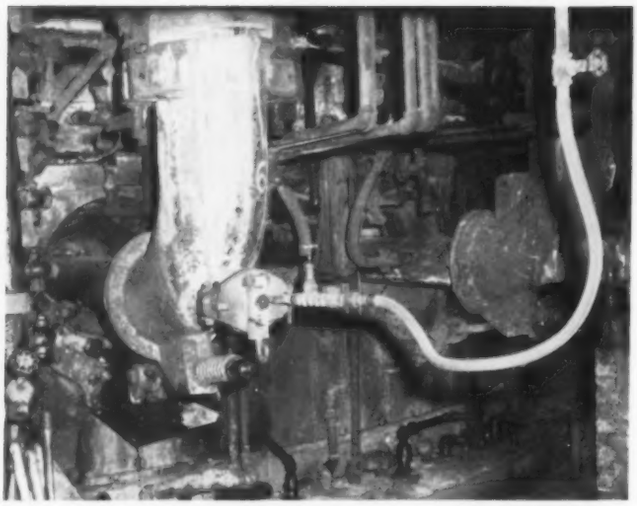


Figure 3 — The injection assemblies were inserted through the caps next to the peep sights.

done by Norwood B. Melcher, of the Bureau of Mines, was released. The results of his work and the results of experiments at Lone Star indicated that a fuel saving and possibly an increase in production could be realized by the injection of natural gas. On November 23, 1959 a full scale test was conducted with natural gas being injected into all of the tuyères. The test was successful and Lone Star Steel Co. has been injecting natural gas continuously since that date.

PREPARATION

Natural gas is supplied to the furnace at 80 psig. The tuyère distribution header consists of two runs of 4-in. pipe, mounted under the bustle pipe, each supplying one half of the tuyères. Figure 2 is a schematic of the piping and control arrangement.

An orifice plate is installed in the supply line to measure total gas flow to the tuyères. A differential transmitter mounted at the orifice location transmits the gas flow signal to the flow recorder mounted in the pyrometer room. Flow of natural gas is controlled by a valve-mounted flow controller, operating a 2½-in. diaphragm control valve.

Electric trip, manual reset safety valves are installed in each section of the natural gas bustle pipe. A safety circuit is provided to trip the safety valves and shut off all gas flow to the tuyères in the event hot-blast pressure drops below nine psig. Gas shutoff push buttons are located at three points around the furnace. This arrangement enables operating personnel to discontinue gas injection in the event of an emergency.

To arrive at a satisfactory method of injection, consideration was given to the use of auxiliary tuyères and to tuyères having special gas ports incorporated in their design. The use of auxiliary tuyères was impractical since it would require that the furnace be down during their installation. Also in using auxiliary tuyères the gas would not be injected into normal raceways of the furnace, and gas utilization might not have been complete. Tuyères could have been purchased or the existing tuyères redesigned to incorporate a gas injection port, but this would have been time consuming.

In the interest of time and economy a decision was made to proceed with the method of injection used in the earlier experiments. A complete set of steel caps were fabricated having ¾-in. standard pipe nipples inserted through them just to the side of the peep sights. The injection pipe assemblies consisted of lengths of ¾-in. standard pipe, with a nozzle of ½ x 6-in. high-nickel alloy pipe to increase gas discharge velocity. The injection assemblies were connected with a pipe coupling to the nipples that had been inserted through the caps. The assembly extended through the blowpipe to within four in. of the tuyère.

Connection between the gas bustle and each blowpipe is made with 1-in. corrugated stainless steel hose. Check valves are placed between each gas hose and injection pipe assembly, to prevent hot blast from entering the natural gas header, see Figure 3. Sections of piping between the gas bustle and each tuyère were made identical. The differential pressures across these sections were used to indicate changes in natural gas distribution.

The furnace was back drafted and the new caps with the gas injection pipes were installed. Natural gas connections were made and the furnace brought up. As soon as full wind was restored and the furnace had moved, gas injection was established at one per cent of the blast volume.

FURNACE REACTION

When natural gas is injected into the furnace, it combines with oxygen in partial combustion to form CO and H_2. Each mol of oxygen used in this reaction liberates less heat than if that mol of oxygen was used in combustion of carbon in coke to form CO. This is because heat is required to dissociate the hydrocarbons in the natural gas, and because sensible heat is required to bring the cold gas up to the temperature of coke inside the furnace. Calculated heat requirements amounted to approximately a 100-F increase in the hot-blast temperature for each gas injection equivalent to one per cent of the blast air volume.

To maintain thermodynamic equilibrium in the furnace, hot-blast temperature was increased 100 F for the one per cent natural gas injection. The tuyères were not as bright as normal, even though hot-blast temperature had been increased. As a result of this, the furnace operators continued to increase blast heat and the furnace became hot. It took several days to become accustomed to the new appearance of the tuyères.

The driving rate of a blast furnace is a function of the rate coke is consumed at the tuyères. Oxygen that would normally burn coke is consumed when natural gas is injected. To prevent the furnace from slowing down, it is necessary that coke input be reduced prior to the time of gas injection. The coke unit was adjusted

TABLE II
Top Gas Analysis, Per cent

	H_2	CO	CO_2	N_2	CH_4	A
Base period	Not available					
Gas injection						
Two per cent	3.96	28.61	9.42	57.05	0	0.97
Three per cent	4.79	28.80	9.64	56.10	0	0.72

to lower the weight of carbon input by an amount equal to the weight of carbon to be injected by natural gas. This coke reduction was made 12 hr (furnace retention time) prior to gas injection. The hydrogen content of the natural gas was not taken into consideration when adjusting the coke unit.

The basic idea behind natural gas injection is to replace a portion of the coke with carbon from natural gas, and to increase the reducing power of bosh gases by hydrogen enrichment. One of the important benefits of natural gas injection is the accelerated rate of ore reduction caused by the higher concentration of reducing gases. Mols of CO and H_2 leaving the tuyère zone per min during a base period (no gas injection) was 98, as compared to 107 with 2-per cent gas injection, and 112 with 3-per cent injection. When the shaft contains stronger reducing gases, the ores entering the bosh zone are more nearly reduced. This will lower hearth temperature requirements because oxides increase the melting temperature of the iron-bearing constituents. For example, FeO melts at a much higher temperature than carbon saturated iron. When lower hearth temperatures are required, lower temperatures are required throughout the entire shaft. As a result, heat losses to the top gas and radiation losses from the shell decrease.

As substantiation of this the water addition made to the skip to control top temperature decreased with increased gas injection. Heat balance data indicated decreased thermal requirements per ton of hot metal with gas injection. Thermal requirements were down by 3¼ per cent with 3-per cent gas injection as compared to 2-per cent injection.

The higher concentration of reducing gases and the fact that less coke is in the shaft exposed to the ascending column of gases will decrease the rate at which the reaction ($CO_2 + C \rightarrow 2CO$) proceeds and solution loss will be lower. Heat balance tests indicate a decrease in solution loss with an increase in gas injection rate.

Heating value of the top gas improved with gas injection. Heating value before gas injection was 90 Btu, as compared to 105 Btu with 2-per cent injection, and 108 Btu with 3-per cent injection. The increase in heating value of the top gas was readily apparent in firing the stoves. A tabulation of top gas analysis with 2-per cent injection and with 3-per cent injection is given in Table II. Note that the concentration of combustible gases, CO and H_2, in the top gas increased from 32.57 to 33.59 per cent, when gas injection increased from two to three per cent. The utilization of hydrogen from natural gas is difficult to accurately determine due to the unknown amount of hydrogen entering the furnace in the form of water. Calculations indicate that approximately 30 to 35 per cent of the hydrogen injected with natural gas has been utilized within the furnace.

FURNACE OPERATION WITH GAS INJECTION

Natural gas was injected at a rate equivalent to one per cent of the blast volume on November 23, 1959. On November 26 gas flow was increased to an equivalent of two per cent of the blast volume. The 2-per cent rate was continued until March 21, when the injection rate was increased to three per cent.

When the furnace leveled out after each increase in the rate of gas injection, it was possible to make further reduction in the coke units; this was compensated for by using higher hot-blast temperature. With natural gas injection the furnace has been receptive to higher heat, moving freely without hanging or slipping. With each reduction in coke the driving rate of the furnace was increased. How much the coke unit can be reduced and still maintain a smooth operating furnace has not been determined. The limiting factor has been available hot-blast heat.

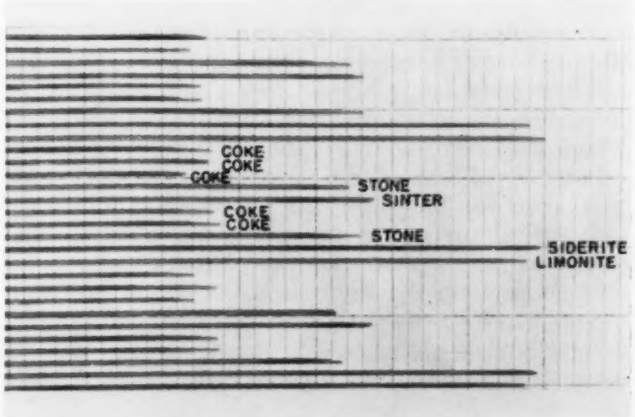
In the early phase of the project it was obvious that the stoves could not maintain the higher heat requirement because of dirty checkers. The furnace was burdened for two stove operation and the stoves were taken off and cleaned. To reduce the amount of material carried into the stoves by the fuel gas, an orifice washer was installed in the downcomer between the dust catcher and gas washer.

To improve stove operation, a new firing practice was initiated. The stoves are now fired with the correct fuel-air ratio until the dome is up to temperature. At this time, to obtain maximum volume through the stoves, the hydraulic cylinders controlling combustion air flow are locked in their open position. Fuel gas flows are then adjusted manually to maintain desired dome temperatures. This arrangement insures maximum volume of gases through the stoves at the highest possible temperature. To assist in heating the stoves the operators were allowed to increase the maximum waste gas temperature from 500 to 600 F.

At the plant location, seasonal atmospheric fluctuations cause blast air humidity to change from a minimum of less than two to a maximum of more than 11 grains of moisture per cu ft. Also rapid changes of four or five grains have been known to occur with storm fronts. To eliminate this variable from furnace operation, humidity control equipment was installed. The installation consists of a humidity detecting unit, a humidity recorder controller and a diaphragm-operated steam flow control valve. Steam is injected into the cold blast main approximately 75 ft ahead of the snort valve.

The second, and possibly most important benefit to be gained from the use of humidity control equipment, is improved utilization of stove capacity. Blast

Figure 4 — The charge cycle and a chart from the skip motor current recorder are shown.



furnace operators in general are reluctant to operate a furnace in a manner that will continuously require maximum possible heat output from the stoves. When the stoves are operated in this manner there is no reserve heat available for use if the furnace swings cold. Steam injection can be used to establish a heat reserve that is readily available when required. For example the furnace may be burdened or natural gas injection adjusted to utilize within 100 F of maximum stove heating capacity. The addition of three grains of moisture will require approximately 100-F increase in hot-blast temperature. The stoves will then be operating at their maximum heating capacity. In the event an immediate increase in hearth temperature is required, steam addition may be temporarily discontinued until relief can be obtained by a burden change.

Some experimenting has been done with blast humidity in excess of 24 grains per cu ft. Results are not encouraging and the smoothest furnace operation has been realized with six to ten grains of moisture per cu ft.

EQUIPMENT DIFFICULTIES

There were two disadvantages to the long gas injection pipes. First, the high temperature in the blowpipe when back drafting caused the injection pipes to warp and lay on the bottom of the blowpipes. Also, each time the furnace came up after back drafting several of the injection pipes were plugged with slag. To correct this condition it was decided to shorten the injection pipes. To reduce sagging when back drafting, the shortened injection pipes were made from ¾-in. type 446 stainless steel pipe with a 6-in. nozzle of ½-in. high-nickel alloy pipe. The shorter pipes extended to within approximately 44 in. of the tuyère.

With higher hot-blast temperatures and increased rate of gas injection, some difficulty has been experienced with gas ignition in the blowpipes. Ignition occurs infrequently, but its effect is serious because in a short time a blowpipe may become overheated and rupture. This problem could have been solved by employing a different method of gas injection; however, it was decided to retain the original method of injection, and provide instrumentation to monitor the blowpipe temperature and sound an alarm when ignition occurred. The instrumentation worked exceptionally well and has consistently warned operating personnel in sufficient time for them to shut off the gas flow to the tuyère where ignition is occurring. Gas ignition is usually caused by a temporary disturbance effecting flow conditions in a particular blowpipe. Usually after an hour or so conditions will return to normal and gas flow may be restored. As an additional safety precaution the blowpipes were lined with a 1-in. layer of high-alumina insulating refractory.

Because of the difficulty experienced with gas ignition in the blowpipes, tests have been conducted with special tuyères having gas injection ports. Test results indicate that the proper place to inject gas is through ports in the tuyères. When the tuyères that are on hand are used they will be replaced by new tuyères having gas ports. Eventually natural gas will be injected through the tuyères rather than through the caps.

EVALUATING GAS INJECTION RESULTS

Heat balance tests were made on the furnace to give an indication of changes in thermal requirements per ton of hot metal as well as possible reductions in heat losses. Analyzing the results from the tests was made difficult because of changes in ore analysis, and other variables. As mentioned previously, Lone Star Steel Co. does not have bedding and blending facilities, and it is practically impossible to obtain samples for analysis that will accurately represent the materials charged throughout a test period. Slag volumes were determined by an MgO balance.

The cooling water piping arrangement made it impractical to use conventional flow metering equipment to determine the flow of cooling water to the furnace. A scheme was employed where a known concentration of fluorescein dye was pumped into the cooling water supply header. After approximately 30 min, when equilibrium had been reached, a series of samples were taken of the cooling water discharge. Dye concentration in the discharge water was determined with a spectrophotometer and compared to the concentration pumped into the supply header to determine flow rate.

Accurate scales are available to weigh the material being charged and a definite charging sequence is established. Nevertheless it was obvious, when obtaining data for heat balance calculations, that a need existed for instrumentation that would produce a record that would indicate weights of material charged and sequence.

During an investigation of the loads being handled by the skip hoist motor it was evident that current supplied to the motor could be used as an indication of weights of material charged as well as the charging sequence. The instrument is a millivolt strip chart recorder used to record current supplied to the hoist motor. The instrument circuit was modified to provide adjustments to cancel the weight of the empty skip cars and provide a means of calibration against known loads from the scale car. A timer holds the recorder out of service during motor acceleration and deceleration periods by opening the input circuit. Figure 4 is a typical chart record.

Heat balance calculations require accurate top gas analysis. The equipment used to obtain this data was a gas partitioner. The equipment performs in much the same manner as an orsat, in that the gas is separated into its components. Recording equipment used with the partitioner produced a chart having a number of traces or peaks corresponding to the number of components present in the sample. Each component traces a definite shape and the trace appears at a definite time interval after sample injection. The area under the trace is related to component concentration. The presence or absence of a particular component can be determined by the presence or absence of a trace at the proper time interval. For example, to determine if methane was present in the top gas, an injection of pure methane was made to determine the time interval of the methane trace. An injection of top gas was then made using a large volume of sample gas and maximum sensitivity. The absence of a trace at the time interval for methane indicated that utilization of the natural gas being injected is complete.

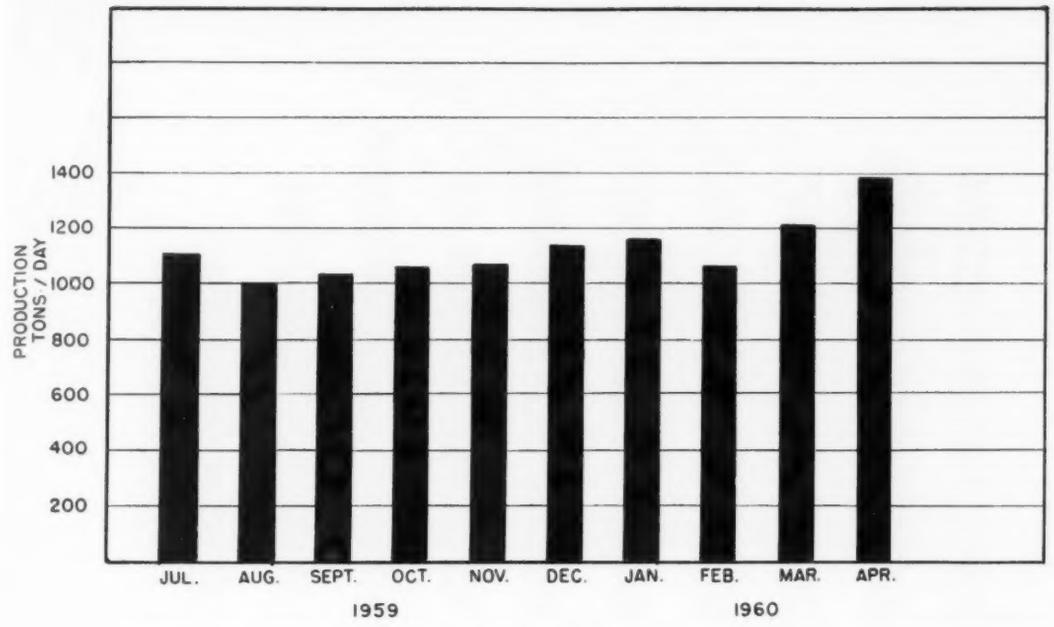


Figure 5 — Monthly production has increased substantially since gas injection was started.

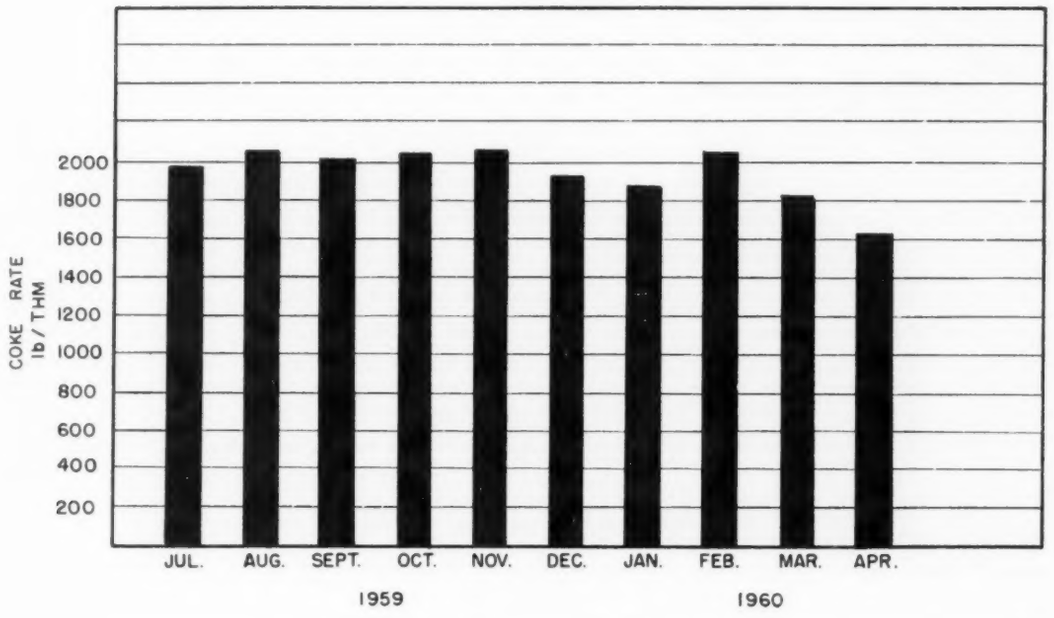


Figure 6 — As the gas injection percentage was increased, the coke rate decreased.

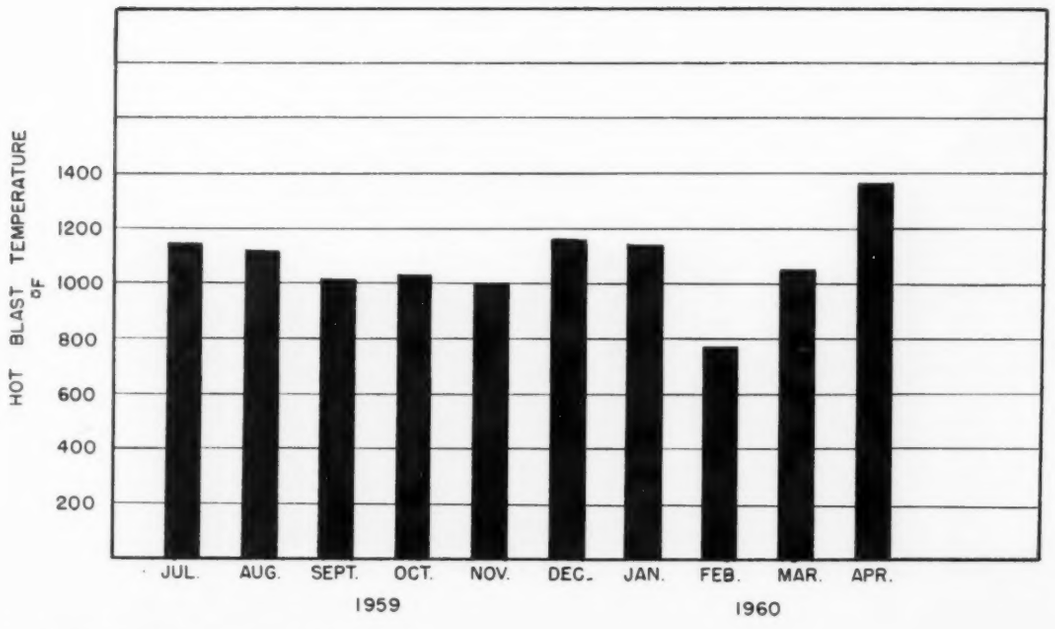


Figure 7 — To compensate for the added cooling caused by the gas injection, the blast temperature was increased.

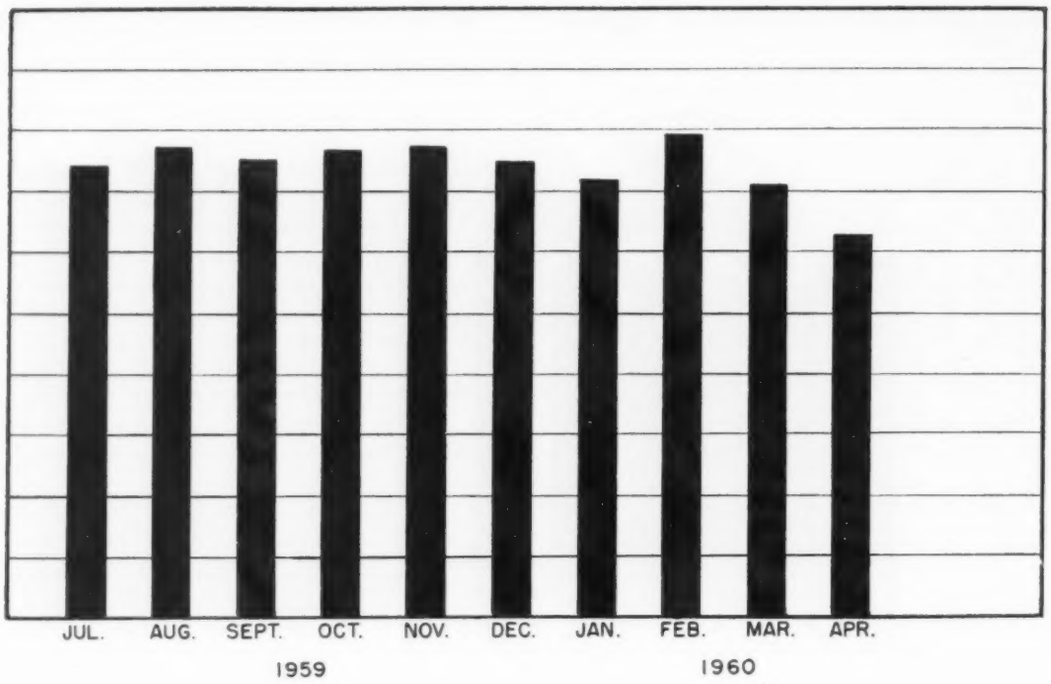


Figure 8 — Fuel costs per ton of hot metal have decreased by 17 per cent.

OPERATING RESULTS

Natural gas injection has attained operator acceptance. The furnace continues to operate smoothly with higher hot-blast temperatures. For example, on numerous occasions the furnace has moved off without checking, when coming up after repair work. The coke rate has been reduced and the driving rate increased.

In order to obtain an over-all picture of the effect that natural gas injection has had on furnace operation, various bar graphs (Figures 5, 6 and 7) have been constructed to indicate relative operation before and after gas injection. By comparing five-months operation before gas injection with five months after gas injection the effect of variables such as Fe content of the ores, slag volumes, etc., can be offset. Because the stoves were down for cleaning during February and March these months are not to be considered as months of normal operation. During the month of April, with 3-per cent injection and average blast temperatures of 1312 F, production increased by 30 per cent, hot-blast temperature increased by 25 per cent and coke rate decreased by 20 per cent.

Bar graphs (Figures 8 and 9) are also shown indicating operational costs before and after gas injection. With 3-per cent gas injection, fuel costs per ton have decreased by 17 per cent and total operational costs per ton have decreased by 15 per cent. Part of the benefit may be attributed to better burden. A graph (Figure 10) is included to indicate the variation in Fe content of the ores.

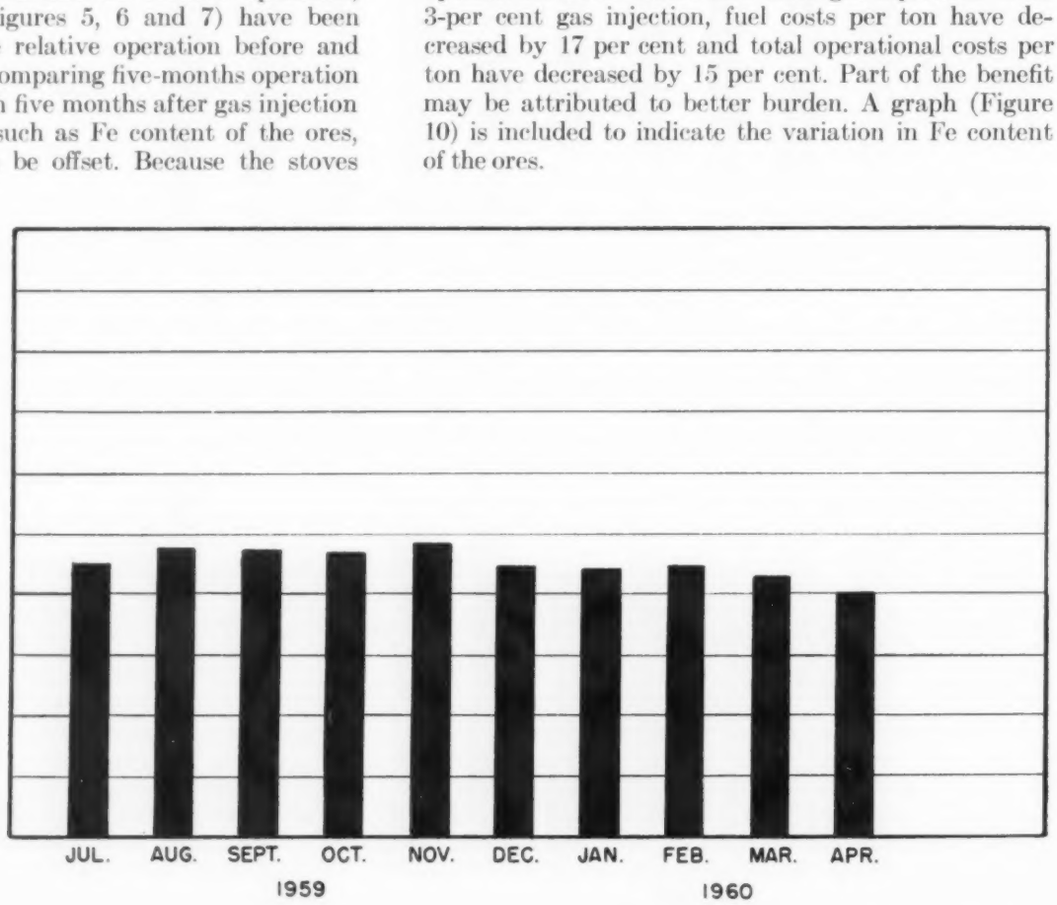


Figure 9 — Total costs per ton of hot metal have decreased by 15 per cent.

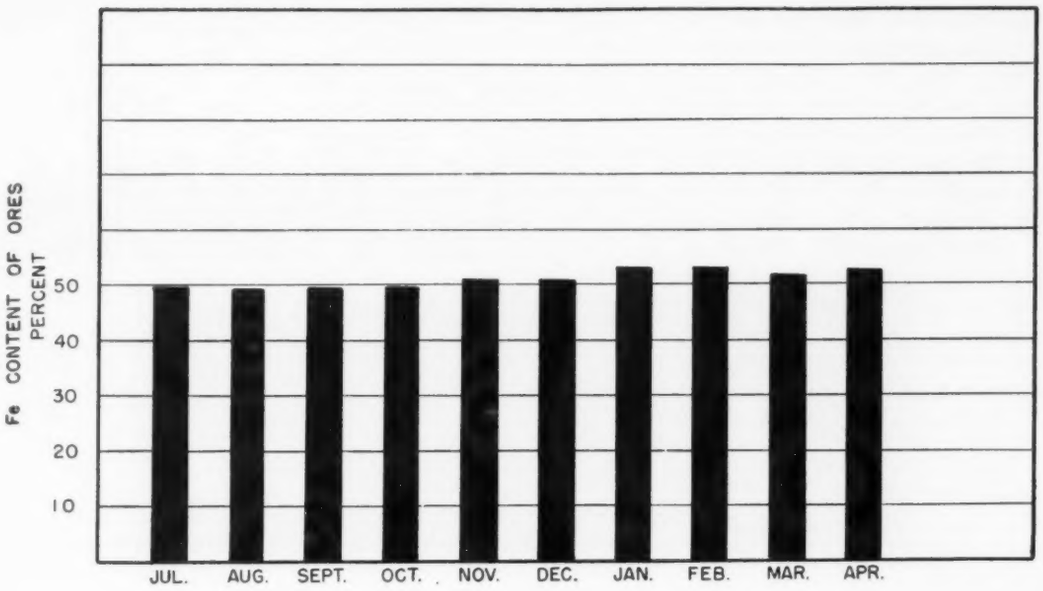


Figure 10 — Fe content of ore increased slightly during the period.

SUMMARY

Natural gas has been injected continuously into all of the tuyères in the furnace at Lone Star Steel for more than a year. Gas injection has reduced the coke rate, and enabled the furnace to operate smoothly with higher hot-blast temperatures. The use of higher hot-blast temperature has increased production.

Because of the reduction in the coke unit, the furnace has more iron-bearing material in the shaft. These materials are in contact with stronger reducing gases for a longer period of time. They enter the bosh more nearly reduced, lowering hearth temperature requirements and contributing to a more efficient furnace.

Three steps were taken when gas was put on the furnace:

1. Carbon (coke) charged into the top was reduced by an amount equal to the lb of carbon to be supplied by the natural gas. The hydrogen content of the gas was not considered during the initial coke reduction. Coke reduction was made prior to the injection of gas. Time between coke reduction and gas injection was furnace retention time.

2. When gas was injected hot-blast temperature was increased approximately 100 F for each 1-per cent gas injection.

3. Coke input was further reduced in small increments; after each coke reduction hot-blast temperature was increased. ▲

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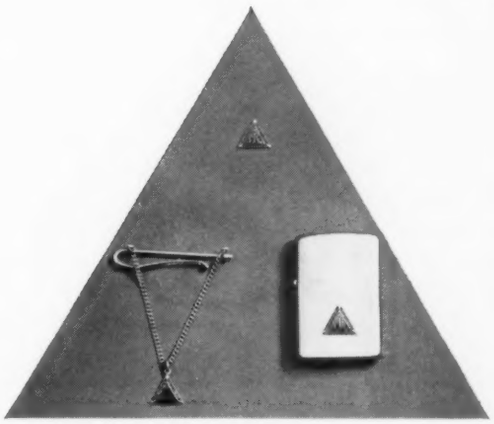


ASSOCIATION OF IRON AND STEEL ENGINEERS

1010 Empire Building **Pittsburgh 22, Pa.**

The Production

THE main object in coating steel with aluminum is to provide a surface which is resistant to corrosion or high temperature scaling. The great affinity between aluminum and oxygen which combine to form aluminum oxide is partially responsible for this protection. In a corrosion resistant coating, the protective aluminum oxide on the coating surface resists chemical attack. In heat resistant coatings, which differ in structure from corrosion resistant coatings, the aluminum oxide forms preferentially to iron oxide at high temperatures. The heat resistance of aluminum-coated steel is well known, and more recently, increasing interest is being shown in its corrosion resistance. In addition to providing corrosion and high temperature oxidation resistance, the advantages in coating steel with aluminum are:

1. Enhancing the appearance of steel.
2. Eliminating dissimilar metal contacts where steel and aluminum are used together.
3. Providing a base for subsequent coating with other materials, organic or inorganic.
4. Providing reflectivity of radiation and lesser absorption of heat.

These advantages may be gained through one or more coating methods which include the following:

1. Spraying, in which aluminum wire is flame melted, atomized and deposited on the steel surface by a gas blast surrounding the flame.
2. Electrodeposition from molten salt or organic liquid electrolytes.
3. Vacuum deposition from condensation of aluminum vapor formed by evaporation at about 2500 F.
4. Cladding in which aluminum is rolled, drawn or extruded into the steel surface.
5. Hot-dip aluminizing in which steel is dipped into molten aluminum.
6. Calorizing or cementation from powder mixtures of aluminum and ammonium chloride at high temperatures.
7. Special process using combinations of aluminum powder with ball milling, the firing of frits and extrusion.

The term "aluminized steel" has been loosely applied to products produced by several of these methods. However, the preference is to associate the term "aluminized" with steel coated by hot dipping to retain the connotation imparted by the similar method of coating steel which is known as hot-dip galvanizing. When aluminized steel is specially treated to obtain a heat resistant coating, it is sometimes referred to as dip calorized steel.

COST CONSIDERATIONS IN ALUMINIZING

Hot-dip aluminizing is considered to be the most economical of the various methods used for coating steel with aluminum. The method is applicable to both the continuous coating of large tonnages of sheet, strip and wire, and to batch coating fabricated items of many shapes and sizes. On the basis of batch coating parts by operations similar to those used in galvanizing and on quotations for commercial jobs of spray coating, the cost ratings for several of the methods of aluminum coating have been estimated to be as follows, in order of increasing costs: [1]*

1. Hot-dip aluminizing
2. Cladding
3. Electroplating and cementation
4. Spraying

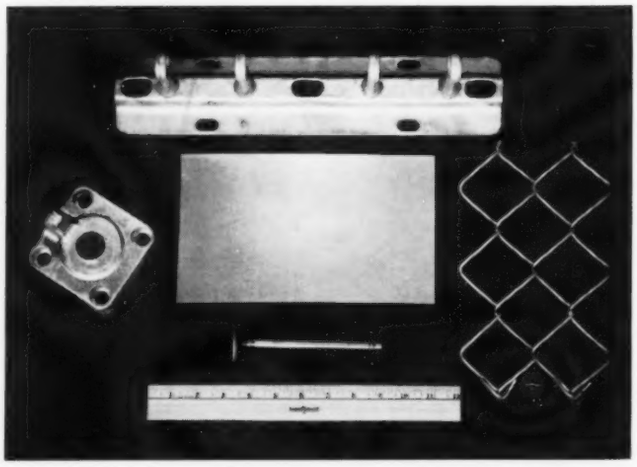
Unfortunately, cost ratings have not been published for the various continuous methods of aluminum coating.

An appreciation of the costs for aluminizing steel may be gained by comparing some of the factors involved in both aluminizing and galvanizing. Generally the thicknesses of aluminum and zinc applied by hot dipping are the same, falling in the range of 0.001 to 0.004 in. thick. Since it has greater specific volume, a given weight of aluminum will cover a greater area of steel (on the basis of equal coating thicknesses). Thus, even though aluminum costs more per lb than zinc, the material costs appear to be in favor of aluminum at present prices.

First costs of equipment in aluminizing and galvanizing may vary from equal to slightly more for aluminizing because refractory pots are recommended instead of the steel pots used in galvanizing. How-

* Numbers in parentheses refer to Bibliography at end of article.

Figure 1 — The parts shown were hot dipped with the exception of the valve which was coated by metal spraying.



And Uses of Aluminized Steel

by JOHN D. SPROWL
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. . . . there are various methods of applying aluminum coatings to steel and all have the same purposes—corrosion and high temperature protection and appearance . . . . hot-dip aluminizing seems to present the most economical and most easily controllable procedure, taking into account alloy composition, temperature and time . . . .

ever, some producers have installed refractory-lined furnaces in galvanizing lines which they may convert to aluminizing simply by changing the metal in the furnaces. Cast-iron pots are being used successfully in aluminizing, although relatively frequent replacement is required.

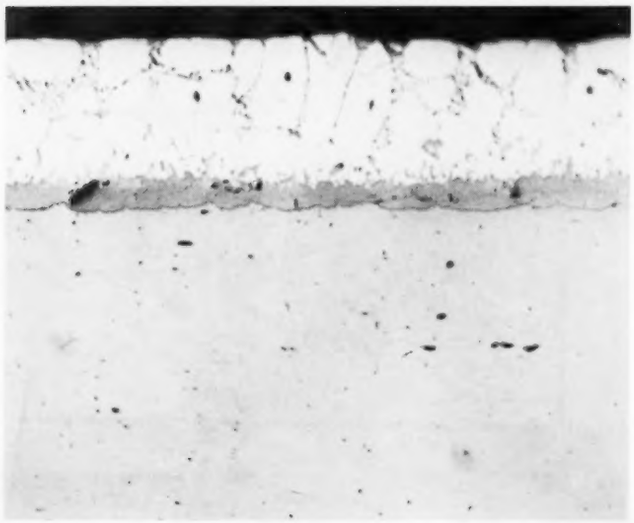
There has been almost no published information regarding the operating costs in hot-dip aluminizing. However, the costs may be slightly greater than those for galvanizing because higher temperatures are used, and, generally, greater care is required to insure that high quality coatings are produced.

To the consumer, aluminized steel means savings, because of the long service life and low maintenance costs of aluminized steel products. These savings have given an advantage to aluminized steel in competition with other coated steel products. To the producer, these savings mean greater demand, and in turn, greater consumption of aluminized steel.

CHARACTERISTICS OF HOT-DIP ALUMINIZED COATINGS

As shown in Figure 1, aluminized steel and iron come in many forms. The coatings on these products consist of: (1) an outermost aluminum layer and (2) an intermediate layer of aluminum-iron alloy called the alloy or interfacial layer, as shown in Figure 2. The aluminum layer, which provides corrosion resistance, may be one of several aluminum alloys. The intermediate alloy layer, which bonds the aluminum to the steel and which consists mostly of the intermetallic compounds, Fe_3Al and FeAl,[2] may be altered in structure and properties by the compositions of both the aluminum layer and the steel base. The steel base may be plain carbon, alloy or stainless steel. In heat resistant coatings, the aluminum is diffused completely into the steel so that the coating consists only of the aluminum-iron alloy.

Figure 2 — A cross section of a hot-dipped item reveals three definite layers: (1) the aluminum coating; (2) an aluminum-iron alloy interface; and (3) the steel base.



Corrosion resistance of the aluminum layer—The corrosion resistance of aluminized coatings stem from the protective oxide on the aluminum surface and the relative insolubility of aluminum corrosion products. Even if the oxide layer is removed by rough handling or abrasion, it reforms immediately to stop attack of the aluminum.

Although aluminum is anodic to iron in the galvanic series, corrosion protection from the aluminum layer

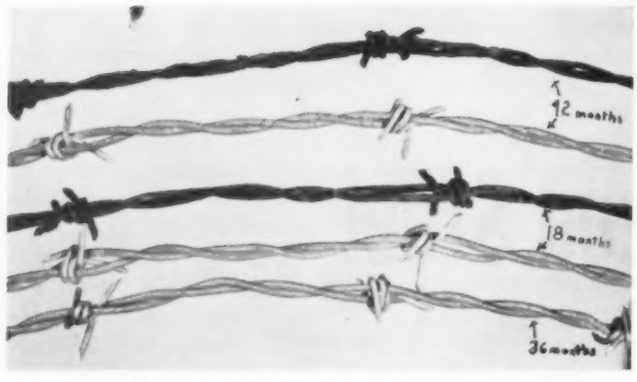


Figure 3 — Marine environment tests indicated that the rate of attack on the aluminized wire is slower than that on the galvanized wire. The galvanized wires are at the top and the middle of the illustration. Barbs on the aluminized wire are of aluminum alloy.

appears to be derived more from physical coverage than from cathodic protection. Hence, occasionally, a rust-like stain occurs on aluminized coatings, but in many cases these stains are temporary and eventually disappear. An explanation for the staining may lie in the nature of the surface oxide on aluminum and the characteristics of the service environment.

In most natural environments, the electrolytes are of low conductivity. Moisture which condenses or forms on the metal surface acts as a high series resistance to depress the flow of current in the galvanic circuit. As a result of this resistance and the added effect of polarization by surface oxide, complete cathodic protection is lacking. Therefore, rust staining may occur at pinholes in the coating and at sheared edges. However, the corrosion rate of this exposed steel is much less than that which occurs when aluminum is not in contact with the steel. Frequently, the rust stains wash away leaving only a dark stain on the exposed steel.

In those natural atmospheres where the conductivity of electrolytes is high, because of high salt concentration, such as marine environments with little rain and fog, aluminum appears to provide some galvanic protection. To provide galvanic protection the coating must be attacked preferentially to the steel, but the rate of attack is slower than that which occurs with other metals used to protect steel cathodically. In these aggressive atmospheres, the greater service life of aluminum coatings becomes apparent, as shown in Figure 3.

Aluminized coatings provide excellent protection to steel in marine, industrial and rural environments. The protection may be enhanced by insuring both continuity and adequate thickness in the aluminum layer of the coating.

Properties of the alloy layer—The alloy layer forms as a result of diffusion between the molten aluminum and the steel. A characteristic of these diffusion-formed intermetallic compounds is an increase in ductility with decreasing thickness. By limiting the proportion of alloy layer to about one third to one fifth of the total coating thickness, aluminized steel sheet withstands moderately severe bending, and aluminized wire may be wrapped about its own diameter without cracking or spalling of the coating.

A thin alloy layer is also desirable when rolling aluminized sheet or redrawing aluminized wire to increase strength or to obtain a bright finish. As the steel and the aluminized coating are reduced simultaneously in thickness, the alloy layer fractures and spreads along the interface between the aluminum and steel. Small fractured particles of a thin alloy layer remain imbedded in the aluminum layer, but large particles from a thick alloy layer may protrude through the aluminum. A consequence of this latter effect is a decrease in appearance from rust-like staining of these protruding particles.

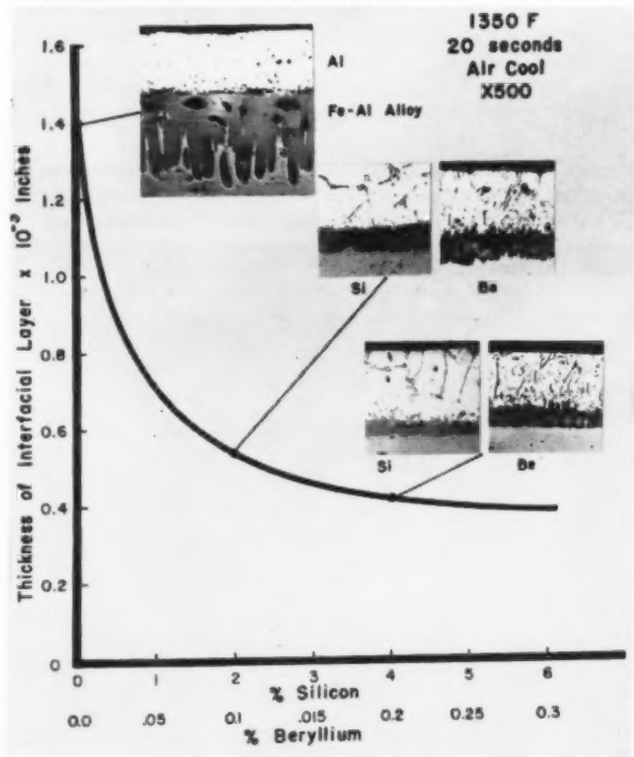
The alloy layer thickness is less important in coatings on fabricated articles, because these items are not usually deformed after coating.

By means of suitable diffusion treatments at temperatures ranging from 1500 to 1700 F, aluminum coatings applied by hot dipping may be converted completely to aluminum-iron alloy. These aluminum-iron alloy coatings protect steel indefinitely from scaling at temperatures up to 1400 F. Since the coatings are brittle, however, deformation will destroy them.

Effects of the coating alloy composition—Depending upon the method of coating steel, the composition of the coating alloy itself may affect the properties of the product. In metal spraying, cladding and vacuum deposition methods, commercially-pure aluminum is used. The coatings resulting from electroplating and halide decomposition methods are also essentially of unalloyed aluminum. In these methods, the composition of the aluminum would have little, if any, effect on properties. However, the properties desired in hot-dip aluminized steel may govern the choice of the aluminum coating alloy.

In hot dipping, the coating alloys are of either commercial purity base or aluminum-silicon alloy to which

Figure 4 — Addition of silicon or beryllium will change the thickness of the aluminum-iron layer.



minor alloying additions may be made. Silicon is used as the major alloying addition for its effect in decreasing the aluminum-iron alloy layer thickness. This effect is produced by beryllium, as shown in Figure 4.[3, 4] Aluminum alloys with from two to six per cent silicon are generally used where ductility is required in the coated product. Unalloyed aluminum may be used where a thicker coating of aluminum is desirable and forming is not so severe. The thicker coating results from both increased diffusion between aluminum and iron and lower fluidity of the molten unalloyed aluminum. As discussed later, the thicknesses of the aluminum and alloy layers' may also be affected to some extent by operating variables in the hot-dip coating process.

Corrosion tests in natural environments indicate that there are no significant differences in the corrosion resistance of commercially-pure aluminum and aluminum-silicon coating alloys when coatings of equal thickness are compared. Alloys containing more than three per cent silicon darken during weathering, but corrosion resistance is unaffected. However, the tendency for heavier aluminum layers to be formed with commercial purity coatings may be advantageous in severely corrosive environments.

Iron content effects ductility, appearance and corrosion resistance in both commercial purity aluminum and aluminum-silicon alloy coatings. Normally, iron is unintentionally added to the hot-dip coating bath through dissolution of the steel being coated and from equipment in contact with the molten aluminum coating bath. Iron up to about two per cent has a beneficial effect on luster of the coating. The presence of iron gives an additional benefit in aluminizing by reducing the rate at which the molten coating bath attacks cast-iron pots.

When more than two per cent iron is present in the coating alloy, the ductility of the coating decreases, the texture of the coating may become rough through precipitation of the Al-Fe intermetallic compound, and corrosion attack on this compound may produce a rust-like stain on the coating. In practice, the iron content may be reduced to 1.5 to 2 per cent by lowering the bath temperature to about 1240 F and sludging.

Small amounts of other alloying elements are sometimes added to the molten coating alloy to improve its characteristics and those of the coating.[5, 6] These secondary additions, which are listed in Table I, are less than 0.5 per cent each.

TABLE I
Functions of Alloying Elements in Aluminized Coatings

Primary additions	
Si	Decreases alloy layer thickness by inhibiting Al-Fe diffusion. Lowers alloy melting point, decreases fluidity of the molten alloy and decreases thickness of aluminum layer.
Fe	Increases luster of coating. Reduces rate of attack of molten aluminum on cast-iron pots.
Secondary additions	
Na	Increases wettability of coating bath.
Be	In small amounts, about 0.001 per cent prevents staining of oxide during quenching. In larger amounts, about 0.05 to 0.25 per cent, decreases alloy layer thickness by inhibiting Al-Fe diffusion.
B, Ti, Cr, Mo, Zr, V, W	Refine grain size and increase luster.
Mo	Increases bath wettability slightly.
Zn, Mg	In small amounts, increase whiteness of coating.

METHODS OF ALUMINIZING STEEL

Aluminizing is, in many respects, like hot-dip galvanizing. Both the continuous and batch aluminizing processes incorporate unit operations which are similar in purpose if not in implementation. These operations may be classified as follows:

1. Cleaning to remove grease, oil, heavy scale and other contaminants.
2. Pickling to remove oxide and to chemically clean the steel surface.
3. Surface conditioning to protect the clean steel surface during heating to the coating temperature and to activate the steel by fluxing.
4. Coating by immersion in the aluminum bath followed by withdrawal.
5. Cooling and finishing.

The most critical operations during hot-dip aluminizing are steps 1 to 3. Failure to obtain and maintain a chemically clean, reactive steel surface prior to immersion in the coating bath invariably results in poor quality, discontinuous coatings.

Numerous descriptions and patents deal with operations for preparing the steel surface for hot-dip aluminizing. The steel is usually cleaned by several methods, including sodium hydride descaling, anodic cleaning in alkaline baths, furnace bluing to burn off oil and grease, and treatment in molten salts and organic solvents. Pickling is done in hot eight to ten per cent hydrochloric or sulphuric acid solution, although hydrochloric acid is preferred. Rinsing between cleaning and pickling is necessary and should be done in hot, fresh water accompanied by scrubbing. After step 2, continuous and batch processes employ somewhat different means to accomplish coating.

TABLE II
Hot-Dip Aluminizing Processes

1. Degrease and clean
2. Rinse
3. Pickle: hot HCl or H_2SO_4
4. Rinse
5. Surface conditioning and heating

Continuous processes	Batch processes
(a) Gas atmosphere, oxidizing and reducing	(a) Molten salt fluxing; fluorides, $BaCl_2 + NaCl$
(b) Predip, aqueous halide solutions	(b) Aqueous predip, $H_3BO_3 + ZrCl_4$
(c) Precoat with copper or glycol	(c) Precoat, wax

(Preheating is in gas or salt flux (a) or in coating bath (b) and (c))

6. Coat
   Aluminum bath at 1250 to 1300 F
7. Cool
   Centrifuge batch material
   Air, spray, quench
8. Finish
   Temper roll, redraw

Continuous processes—While many methods of continuously coating steel have been described in the literature, only three basic processes are currently used to any significant extent. These processes may be classified by the method used to activate and protect the steel surface prior to its immersion in the coating bath. As shown in Table II, these processes include: (1) oxidation of the steel followed by reduction of the oxide in a gas atmosphere; (2) predip in aqueous salt solution and (3) precoating with copper or glycol. The gas atmosphere and predip methods are used in the United States, while the precoat method is used in England.[7]

In the gas atmosphere method used by a large producer in the U. S., the clean steel is heated to a fairly high temperature in air to form a thin oxide film on the steel surface. The oxide is then reduced in a dry, high temperature atmosphere of hydrogen to form a layer of reactive elemental iron on the surface to be coated. Following this, the heated steel passes through a downspout, still in its reducing atmosphere, to enter the molten aluminum coating bath which is held in the temperature range of 1250 to 1300 F. In a variation of this process, successful coating was done on a pilot line in which the cleaned steel was merely heated to about 1400 F and transported to the coating bath in a protective atmosphere consisting of ten per cent hydrogen and 90 per cent nitrogen.[3]

The gas atmosphere process has an advantage in coating sheet in that the temperature of the molten aluminum may be partially maintained by heat input from the heated steel. Thus, heating requirements to maintain the coating bath temperature by external means may be less than those in the predip and precoat methods.

The aqueous predip method is one which is used for aluminizing wire. The cleaned steel is immersed in a hot aqueous solution of alkali metal salts. Evaporation of the water, aided by slight external heating, leaves a residual film of salts on the steel surface. The film of salts protects the surface from re-oxidation and serves as a mild flux on the steel when it enters the coating bath. A solution of potassium, titanium and/or zirconium fluoride has been used successfully.[3] Since the steel is at only moderately-elevated temperatures when it enters the aluminum coating bath, an external heat source is necessary to maintain the bath temperature. Thus, the process appears to be well suited to the coating of wire.

The precoat process consists of coating the steel with copper, which readily alloys with molten aluminum, or with glycol, which protects the steel surface until it enters the coating bath. A disadvantage of the copper precoat process is that accumulation of copper in the coating bath decreases the corrosion resistance of the aluminum coating.

Batch processes—Batch coating processes fall into two categories: (1) molten salt bath processes and (2) predip processes. The gas atmosphere process is not considered to be practical for batch processes. The operations involved in the salt bath and predip batch processes are also shown in Table II.

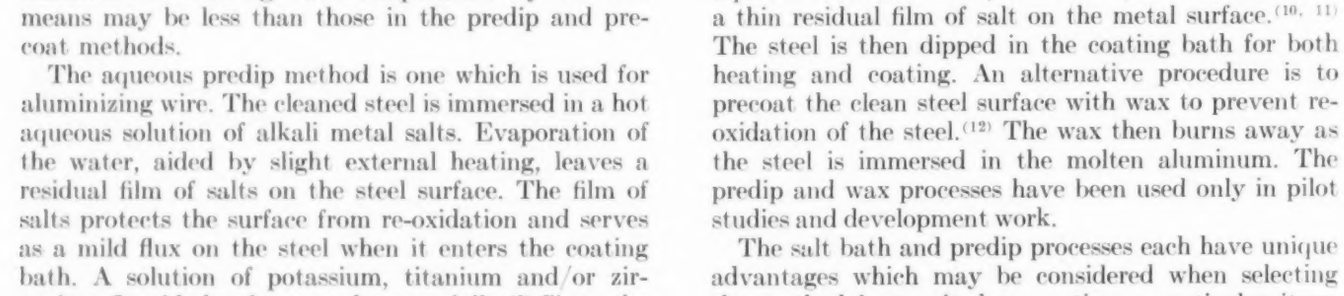
Two patented salt bath processes are used on a commercial scale. In one process,[8] a molten mixture of alkali halide salts is contained in a submerged electrode furnace. A layer of molten aluminum is located beneath the salt. The cleaned steel is immersed in the salt for preheating and fluxing after which it is either immersed in the underlying molten aluminum or transferred to another furnace, containing molten aluminum, where it is coated.

In the other salt bath process,[9] a molten mixture of barium and sodium chlorides is contained in a submerged electrode furnace. A layer of molten aluminum, which is less dense than the molten salt, floats on top of the bath, and its temperature is maintained by the heat of the salt. The cleaned steel is immersed in the furnace either directly into the salt, or through the molten aluminum float into the salt, where it heats to the coating temperature. Coating is completed by withdrawing the steel through the aluminum.

The predip process resembles that used for continuous aluminizing. The cleaned steel is immersed in an aqueous solution of salts, withdrawn, and dried to leave a thin residual film of salt on the metal surface.[10, 11] The steel is then dipped in the coating bath for both heating and coating. An alternative procedure is to precoat the clean steel surface with wax to prevent re-oxidation of the steel.[12] The wax then burns away as the steel is immersed in the molten aluminum. The predip and wax processes have been used only in pilot studies and development work.

The salt bath and predip processes each have unique advantages which may be considered when selecting the method best suited to coating a particular item. In the salt bath process, salt is entrained with the aluminum as the coated part is removed from the coating bath. The presence of salt flux on the molten aluminum surface prevents the formation of aluminum oxide, and the absence of oxide, in turn, facilitates the removal of excess molten aluminum from threaded parts during centrifuging. On the other hand, salt flux which re-

Figure 5 — Thickness of the aluminum coating can be controlled by varying several factors.



mains on the surface of the solidified coating must be removed to obtain maximum corrosion resistance from the coating.

Use of the predip process entails less elaborate furnaces for containing the aluminum coating bath because simple crucible or cast-iron pot furnaces are satisfactory. Moreover, the coated steel is in its finished form when the coating has solidified. No further treatments are necessary. However, the removal of excess coating on threads is difficult because of the oxide which forms on the surface of the molten coating. It has been determined experimentally, that the use of a special planetary centrifuge may be an effective means of overcoming this difficulty.[13]

A special application of batch aluminizing is involved in the process whereby aluminum is cast around steel.[14] The cleaned steel is precoated with aluminum, usually by the salt bath process. Then, while the aluminum coating is still molten, the part is placed in a suitable mold and aluminum is cast around it. The result, of course, is a steel product bonded to a heavy aluminum coating or a casting.

Effects of operating variables—During hot-dip aluminizing several variables besides the coating alloy composition influence the thicknesses of the aluminum and alloy layers in the coating. The effects of some of these variables are shown in Figure 5.

The temperature of the coating bath and the time during which the steel and molten aluminum are in contact partially determine the rate and extent of diffusion between the aluminum and steel. Thus, the thickness of the alloy layer may be decreased and, in turn, ductility of the coating increased, by coating at temperatures in the range of 1250 to 1300 F with a minimum immersion time. An additional benefit from operating under these conditions is insuring the application of the thickest possible aluminum layer for corrosion resistance.

Higher coating bath temperatures promote rapid growth of the aluminum-iron alloy layer and also increase the fluidity of the molten coating so that a thin aluminum layer may result, as shown in Figure 6. This combination of thick intermetallic alloy and thin aluminum layers produces losses in coating ductility and corrosion resistance.

Higher speeds of withdrawal from the coating bath and more rapid cooling after coating also increase the thickness of the aluminum layer. The thickness of aluminum which may be gained through increased withdrawal speed is limited to about 0.003 in. but rapid cooling augments rapid withdrawal by freezing the coating and stopping both draining and diffusion which continue while the coating remains molten. Large batch-coated objects usually require rapid cooling to prevent complete diffusion of the aluminum coating into the steel.

MARKETS FOR ALUMINIZED STEEL

The markets for aluminized steel are potentially the largest for any coated steel product, because aluminized coatings are the basis for improving both the corrosion and heat resistance of steel. At the present time, the largest consumer is the automotive industry where aluminized mufflers are standard equipment on several

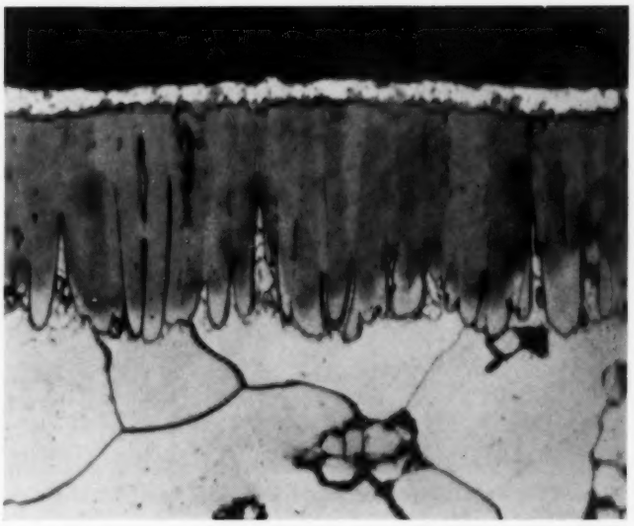


Figure 6 — Thick intermetallic alloy layers produce a reduction in ductility and corrosion resistance.

makes of automobiles. In the electrical transmission industry, aluminum cable with aluminized steel core wire (ACSR) is now available. Other applications of wire include strand cable and farm fencing. Aluminized steel provides an excellent base for painting and porcelain enameling. The heating, ventilating and appliance industries employ aluminized steel for both corrosion and heat resistant applications. The petroleum industry has found that aluminized steel sheathing and piping are especially resistant to the sulphur-containing gases in their product streams. Pole line hardware and fasteners of aluminized steel for use with aluminum structurals are becoming available in quantity. A few of the applications of aluminized steel are illustrated in Figures 7, 8, 9 and 10.

ALUMINUM COATING BY OTHER METHODS

Although aluminizing is the method by which most of the corrosion resistant aluminum-coated steel is produced, several of the other methods are also in use or in development. These methods form an interesting complement to a discussion of aluminizing because they illustrate the versatility of aluminum as a coating metal. Coatings produced by these methods may range in thickness from several hundred Angstrom units on ornamental applications as obtained by vacuum deposition, to over 0.040 in., as obtained by metal spraying, cladding and the use of aluminum powders.

Metal spraying—Aluminum is usually sprayed on steel by means of a wire pistol where the aluminum is melted in an oxyhydrogen or oxyacetylene flame. The molten metal is then atomized and carried to the clean steel surface as small globules by a blast of compressed air surrounding the flame. The pistols may be manually or automatically operated and, in the latter case, a multiplicity of nozzles may be arranged in rows or angle formation. Each nozzle is fed individually and the wires are passed through the nozzles by electrically-driven feeds. Generally, the surface to be sprayed is cleaned by rough machining or grit blasting.

Since the metal is deposited as small globules, the coating consists of small metal particles surrounded by a

Figure 7 — Aluminized steel is being used in the production of mufflers.

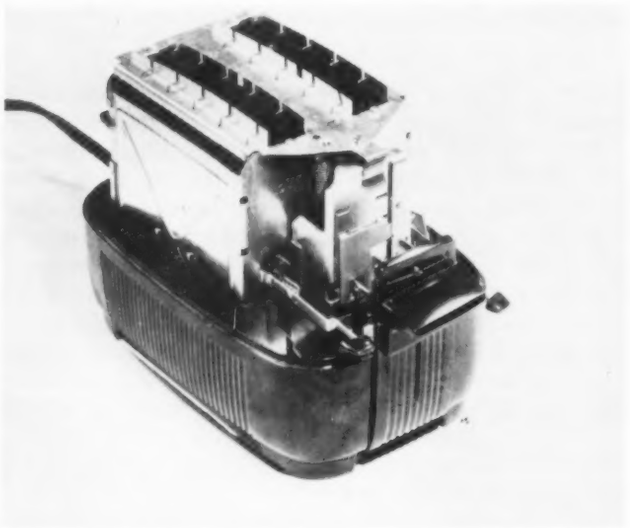


Figure 8 — Both heat resistant and corrosion resistant properties are necessary in this application.

thin oxide film and some porosity. The bonds between particles and between the coating and the steel appear to be mechanical. Thus, a sealing treatment is usually required to improve corrosion resistance or to prevent oxidation of the steel base when a diffusion treatment is used to produce a heat resistant coating. Sealers which are applied to the coating include bitumastic compounds and ethyl silicate.

There are no limitations on component or structure size or on the thickness of coating which may be applied in metal spraying. Recesses, corners, joints and undercuts are easily coated. Metal spraying has been suggested for recoating weldments in hot-dip aluminized steel. Furthermore, the equipment for coating may be transported to the structure, if necessary. Thus, metal spraying is particularly suited to coating large structural shapes such as the reactors and long piping used in petroleum refineries.

Cladding—Although the production of clad steel is relatively small, the products have attractive properties which may induce more manufacturers to adopt this method of protecting steel. Moreover, the extensive research done in cladding other metals with aluminum in the nuclear power industry may be applied in the future to cladding steel.

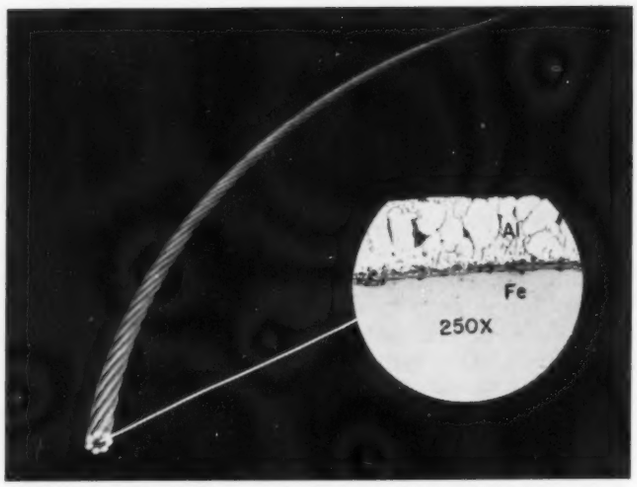


Figure 9 — Aluminized steel core wire reduces corrosion and dissimilar metal contact problems.

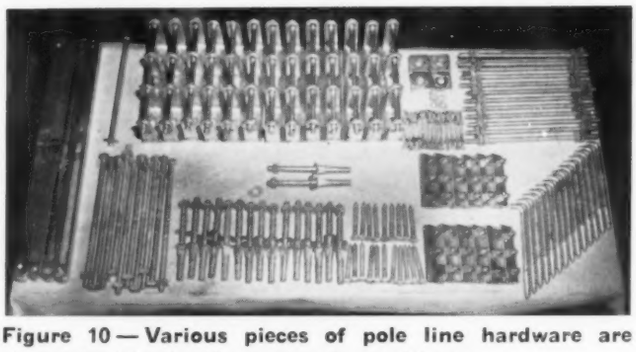


Figure 10 — Various pieces of pole line hardware are aluminized to give them corrosion resistance.

According to descriptions in the literature,[15] cold-rolled and annealed aluminum strip of 0.008 in. thickness is coiled on special reels mounted above and below steel strip at the entrance to the bonding roll stand. Preliminary to bonding, the steel strip is cleaned and then roughened with rotary wire brushes. Sandwiched between the aluminum strips, the steel is rolled under high tension at a temperature of about 350 F. This temperature is produced by the work of rolling and not by separate heating. After rolling the clad metal is rerolled to desired gage, coiled and then annealed 10 to 15 hr at about 1000 F to improve the bond between the aluminum and steel. Critical variables in roll bonding are surface preparation of the steel, temperatures of rolling and the amount of reduction.

Clad steels are characterized by excellent coating ductility and absence of pores and discontinuities in the coating. For this reason they are employed in applications where severe corrosion is encountered. However, they exhibit the same limitations as hot-dip aluminized steel where sheared edges are exposed.

Electroplating—Electroplating aluminum on steel has had limited application. Because of high hydrogen overvoltage, electroplating aluminum from aqueous solutions is not practical. Consequently, research efforts have explored the use of fused salts and organic solutions as electrolytes, but these plating solutions involve the use of high temperatures and volatile, combustible materials. Moreover, the throwing power of these baths is poor and current efficiencies are so low that the coating is deposited slowly. Because the coating is thin and no aluminum-iron alloy layer is present, good coat-

ing ductility is obtained. However, corrosion resistance is considerably less than that obtained from hot-dip aluminized coatings.

Electroaluminum coatings have been considered as a replacement for electrotin.

Vacuum deposition—This method of depositing thin aluminum coatings on plastics, metals and glass for ornamental purposes is old to the art. However, recent developments indicate that the deposition of relatively heavy coatings on steel for corrosion resistance may become important commercially. Pilot-plant development has proceeded to the point where steel is coated on a continuous basis by this method.

According to one description,[16] thoroughly cleaned steel is placed in a chamber which is evacuated to a pressure of about 0.5 micron Hg absolute. An aluminum filament is then evaporated at about 2500 F and the aluminum vapor condensed on the steel surface to form the coating. The thickness of the deposited coating is proportional to the length of time the steel is presented to the aluminum vapor. Other important factors in the process are the distance of the steel surface from the aluminum source, and the temperature of the steel surface during deposition of the aluminum. Reportedly, adhesion of the coating is improved by heating the coated steel to 350 to 700 F.

An obstacle in applying heavy aluminum coatings by deposition has been the difficulty in obtaining materials to contain substantial quantities of aluminum at temperatures of 2500 F. At this temperature, aluminum is virtually a universal solvent.

Heavy vacuum deposited aluminum coatings display excellent ductility and freedom from porosity.

Methods using aluminum powder—Recently a method using aluminum powder was described as a means of applying thick coatings of aluminum on steel wire.[17] Electrical conductor (EC) grade aluminum powder is compacted under heat and pressure on a cleaned steel wire. The composite wire may then be redrawn to obtain the desired gage or increased strength. The coating thickness may represent a significant proportion of the wire cross section so that the composite can be used as a combined load member and electrical conductor in service. Corrosion tests indicate that the corrosion resistance of the clad wire is equal to that of EC aluminum conductors provided that the cladding job is of high quality.

The patent literature describes another method of aluminum coating in which aluminum powder is used.[18] A mixture of aluminum powder and water soluble flux in an organic vehicle, such as methanol, is sprayed, painted or otherwise applied to a clean steel surface at room temperature. The part is then heated for several minutes in a nitrogen atmosphere at 1300 F which melts the aluminum in the flux to coat the steel. After coating the flux is rinsed off in hot water and hot nitric acid solution. A satin finish may be obtained by vapor-grit blasting. Depending upon the time of heating at 1300 F, the finished coating may be used either for corrosion resistance or heat resistance. In the latter case, heating is prolonged to complete the diffusion between the steel and aluminum.

Other methods using aluminum powder involve blasting the steel surface with powder, similar to grit blasting, which causes the powder particles to adhere to the steel and to each other. A similar principle is involved where aluminum powder, the steel part, and other materials are tumbled in a mill to build up the coating on the steel surface. However, outside of the patent literature, little has been published about these methods.

THE FUTURE OF ALUMINUM-COATED STEEL

Aluminum-coated steel is an accepted product in many industries, and its uses are increasing. A measure of this growth is the increase in the consumption of aluminum for aluminized steel, as given by figures in Table III (from the AISI):

TABLE III
Consumption of Aluminum for Coating Steel

Year	Lb
1960	7,000,000 (estimated)
1959	5,554,000
1958	4,076,000
1955	1,028,000
1952	164,000

Perhaps the most important phase in the development of aluminum-coated steel is the continuation of field tests and the dissemination of information demonstrating the advantages of aluminum-coated steel products. When tests now in progress continue to show the excellent performance of high quality products, particularly in corrosive environments, it may be expected that the demand will exceed the supply, as is the case in the hot-dip aluminized sheet industry today.[19] Many methods are available for aluminum coating steel, and it is expected that technological advances in these methods will give additional impetus to wider use of aluminum-coated steel products.

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13. J. B. Russell, et. al., U. S. Patent 2,804,976, September 3, 1957.
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17. "Alumoweld Wire a New Aluminum Coated Wire with a Thick Coating," by L. C. Whitney, Wire and Wire Products, November 1958, pp. 1362–1364, 1413.
18. A. R. Stetson, U. S. Patent 2,927,043, March 1, 1960.
19. Iron Age, September 1, 1960, p. 41. ▲

CURRENT AISE DISTRICT SECTION MEETING NOTICES

BIRMINGHAM SECTION

Monday, November 27, 1961—Social Hour 6:30 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Hydraulics as Applied to Modern Machinery," by A. H. Laird, District Manager, Vickers, Inc., Atlanta, Ga.

Redmont Hotel, Birmingham, Ala.

BUFFALO SECTION

Tuesday, November 14, 1961—Dinner 6:30 P.M., Meeting 8:00 P.M.

"Modern Trends in Billet Conditioning," by R. F. Dunlavey, Superintendent of Finishing, Republic Steel Corp., Buffalo, N. Y.

Hotel Sheraton, Buffalo, N. Y.

CANTON SECTION

Details Not Available.

CHICAGO SECTION

Tuesday, November 7, 1961—Dinner 6:15 P.M., Meeting 7:45 P.M.

"World Ore Supplies," by R. M. Lloyd, Administrative Vice President International Mining, United States Steel Corp., Pittsburgh, Pa.

South Shore Country Club, South Chicago, Ill.

CLEVELAND SECTION

Tuesday, November 28, 1961—Dinner 6:30 P.M., Meeting 7:45 P.M.

"Use and Future of Scrap in the U. S. A.," by Wm. R. Magness, Luria Bros. & Co., New York, N. Y.

"Expansion at Reserve Mining," by F. M. Darner, Chief Engineer, Manufacturing Div., Republic Steel Corp., Cleveland, Ohio

Third paper data not available.

Cleveland Engineering and Scientific Center, 3100 Chester Avenue, Cleveland, Ohio

COLORADO SECTION

Details Not Available.

DETROIT SECTION

Monday, November 13, 1961—Dinner 6:30 P.M., Meeting 8:00 P.M.

J&L Stainless & Strip Division Night

"Maintenance Aspects of All Purpose Railroad Bearings for the Steel Industry," by T. C. Keller, Chief Engineer, Railway Engineering Dept., The Timken Roller Bearing Co., Canton, Ohio

Dinner and Meeting, Main Ball Room, Dearborn Inn, Dearborn, Mich.

LOS ANGELES SECTION

Monday, November 13, 1961—Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Continuous Galvanizing," by Gordon C. Turner, Chief Engineer, Sheet and Strip, Aetna-Standard Div., Blaw-Knox Co., Ellwood City, Pa.

Michael's Restaurant, 6309 E. Washington, Los Angeles, Calif.

PHILADELPHIA SECTION

Saturday, November 4, 1961—Dinner 6:00 P.M., Meeting 7:00 P.M.

"The World—and Steel—and You," by D. O. Davis, Vice President, Engineering, Dominion Foundries & Steel, Limited, Hamilton, Ontario, Canada

"Rolling of Structural Steel," by R. E. Shaffer, Superintendent, Roll Dept., Saucon Div., Bethlehem Steel Co., Bethlehem, Pa.

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

PITTSBURGH SECTION

Monday, November 13, 1961—Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Scrap Charging in Steelmaking Furnaces," by D. R. Loughrey, Consultant to Open Hearth Superintendent, Pittsburgh Works Div., Jones & Laughlin Steel Corp., Pittsburgh, Pa.

University Club, University Place, Pittsburgh, Pa.

ST. LOUIS SECTION

Wednesday, November 29, 1961—Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

Gear Tooth Forms for Steel Mill Service," by John J. Stolz, Assistant Vice President, Engineering, The Tool Steel Gear & Pinion Co., Cincinnati, Ohio.

Elks Club, Granite City, Ill.

SAN FRANCISCO SECTION

Wednesday, November 15, 1961—Social Hour 6:00 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

Judson Steel Corp. Night

"Continuous Galvanizing," by Gordon C. Turner, Chief Engineer, Sheet and Strip, Aetna-Standard Div., Blaw-Knox Co., Ellwood City, Pa.

Spenger's Fish Grotto, 1919 Fourth St. (near University Avenue), Berkeley, Calif.

UTAH SECTION

Saturday, November 4, 1961—Social Hour 6:30 P.M., Dinner 7:30 P.M., Meeting 8:30 P.M.

"Blast Furnaces," by R. L. Stephenson, Chief Research Engineer, Applied Research Laboratory, United States Steel Corp., Monroeville, Pa.

Grandview Cafe, Provo, Utah

YOUNGSTOWN SECTION

Monday, November 27, 1961—Social Hour 6:30 P.M., Dinner 7:00 P.M., Meeting 8:00 P.M.

"Automation Possibilities for Future Mills," by W. E. Korsan, Assistant Manager Industrial Systems Dept., Industrial Equipment Div., Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

Mahoning Country Club, Girard, Ohio

Stability of Steel Plant Electrical Systems

by K. S. KUKA
Chief Electrical Engineer and Director
M. N. Dastur and Co., Private Ltd.
Consulting Engineers
Calcutta, India

. . . . the extensive interconnections of the electrical system of a modern steel plant require adequate protection and controls to prevent long and costly shutdowns due to high-voltage faults . . . . analytical study of the system using a network analyzer is essential if such protection and controls are to assure maximum operational stability . . . .

CONTINUITY of operations in an integrated steel plant is of vital importance. Shutdowns cause heavy financial losses, as even a relatively short interruption can result in long stoppages of the interrelated production processes. Modern design technique of electrical switchgear and controls is so advanced that factory-assembled and factory-tested equipment should be installed where chances of faults are to be reduced to a minimum. It should be appreciated that there is no substitute for good quality, well-designed equipment. Due to stresses and strains to which machines are exposed, troubles do occasionally occur, and it is essential that the design engineer studies the plant stability requirements under the different possible fault conditions.

Characteristics of steel plant loads are such that large blocks of power concentrate in relatively small areas. This results in the development of very large short circuit power which tends to flow at the point where a fault occurs. This creates problems of voltage disturbances in the plant electrical system. As the power system in a modern steel plant is extensively interconnected, the voltage disturbance caused by a system fault spreads over a large area, creating widespread disruptions to the plant operations wherever voltage sensitive equipment is in service. The power system engineer and the control designer have to be constantly searching for facts, logic and analytical data on the various aspects of the electrical operations and provide a co-ordinated system where disturbances to plant services are reduced to a minimum in the event of a heavy fault on the system.

Most integrated steel works generate their own power and also purchase additional power from an electrical utility company. The plant power distribution system operates as a large interconnected network with several powerhouses operating in parallel. The effects of a fault on such an interconnected system have therefore to be considered if stability of plant operations is to be ensured.

Analytical study of the electrical distribution system on a network analyzer is considered essential for the planning of the power system for an integrated steel plant. Such a study should include both steady-state power flow and transient stability conditions of the system as a whole, as well as system short circuit study, relay study, study of voltage drops, and selection of electrical controls to ensure maximum stability under severe voltage disturbances.

The problems are so varied and of such vast magnitudes that it is not easily possible to discuss each aspect in a single discussion. In this article, some of the important features of the electrical system stability are discussed as could be applied in actual practice when a steel plant power system is designed.

POWER DISTRIBUTION SYSTEM

In Figure 1 is given a schematic representation of electrical distribution system of an integrated steel plant which has developed over the years. This has resulted in the adoption of increasingly higher voltage ratings for plant power distribution. The system has a 15-min integrated demand of about 126 mw (145 mva) of which about 75 mw is generated and the rest purchased from a public utility system. The purchased power is taken at 132 kv and stepped down to 33 kv for interconnections with the works system. The works generation is over two powerhouses, one

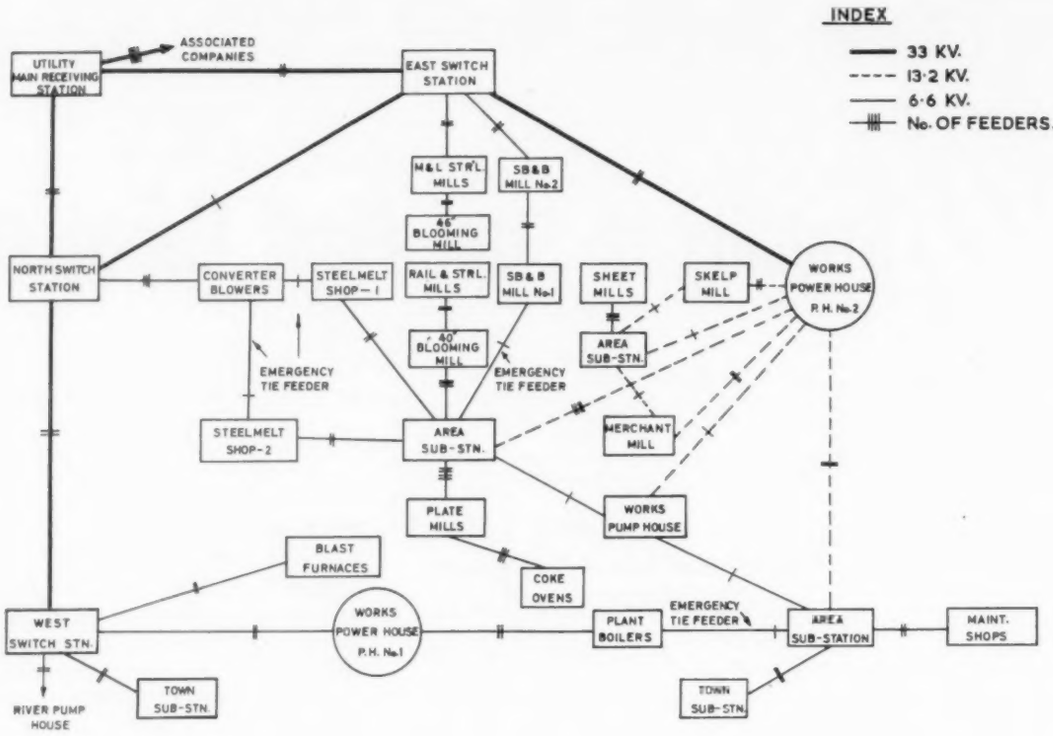


Figure 1 — Schematic representation illustrates the electrical distribution connections of an integrated steel plant.

connected with the blast furnaces, using surplus blast furnace gas and coal middlings from the coal washeries, while the other powerhouse operates as a base load station. These two powerhouses are termed PH1 and PH2.

STEADY-STATE POWER FLOW

In Figure 2, the main system interconnections and the works main substations are indicated, showing the paralleling of the works system with the utility power system. In the diagram, the base powerhouse (PH3) of the utility system is shown, to which the steel works power system is connected.

For maximum continuity of power supply, it is essential that the electrical system is planned on a firm power capacity basis. The firm power means that the capacity at each major station shall be such that allowing for maintenance outages, generation as well as the feeder availability shall meet the plant maximum demand at the station even if the largest operating unit suddenly goes out of service for any reason.

The purchased power is normally charged on the basis of a 2-part rate, namely, a monthly charge based on a 15-min or a 30-min integrated demand in kva and an energy charge per kwhr for the total energy consumed. Normally, the demand charge payment has also to be guaranteed as a minimum, generally at 75 per cent of the declared contract demand in kva.

In the case of steel plants having their own generation, the power utility companies normally offer tariffs with a high demand charge and a low energy charge, in order to discourage the firm drawing power from the utility system at low load factors, where the customer might attempt to transfer short-time peaks to the utility system. With such a 2-part rate, it is essential to estimate the maximum demand to be declared as the contract demand for the power agreement. The purchased power would be most economical when the demand is maintained within the limit of the declared contract demand and the power is drawn at high load factor.

To determine the suitable contract demand, an a-c network analyzer study is useful. Figure 2 indicates such a load study for a steel plant system. The kw and reactive kva power requirements have been indicated under the peak load conditions of the system. The transformer taps are shown so adjusted that the bus voltage of each of the major stations of the steel plants system is at about 100 per cent base voltage.

In the example, the steel plant has two powerhouses with a total of three machines always in operation, PH1 with one 18-mw, 0.8-power factor, 3.15-kv turbogenerator associated with the blast furnaces, and PH2 with two 30-mw, 0.8-power factor, 13.2-kv machines as a coal-fired base load station. The utility power company has six hydro and steam generating stations operating on the system. In Figure 2, only one steam station PH3 is shown which is directly connected with the steel plant system over 132-kv double-circuit transmission lines about 100 miles in route length.

The 15-min demand of the steel works system is estimated at about 126 mw with a maximum of works generation of about 75 mw. It would thus be necessary to import about 51 mw of additional demand from the utility system. In order to ensure the firm power demand of the works, the contract demand with the utility system has to be based on the assumption that one 30-mw unit drops out from the system. The contract demand has therefore to be based on at least 80-mw load. The maximum power that may be required to be drawn from the utility system would therefore be 80 mw and 46 mvar, or about 92 mva. The contract demand for the power supply agreement for maximum

security will thus be 90 mva.

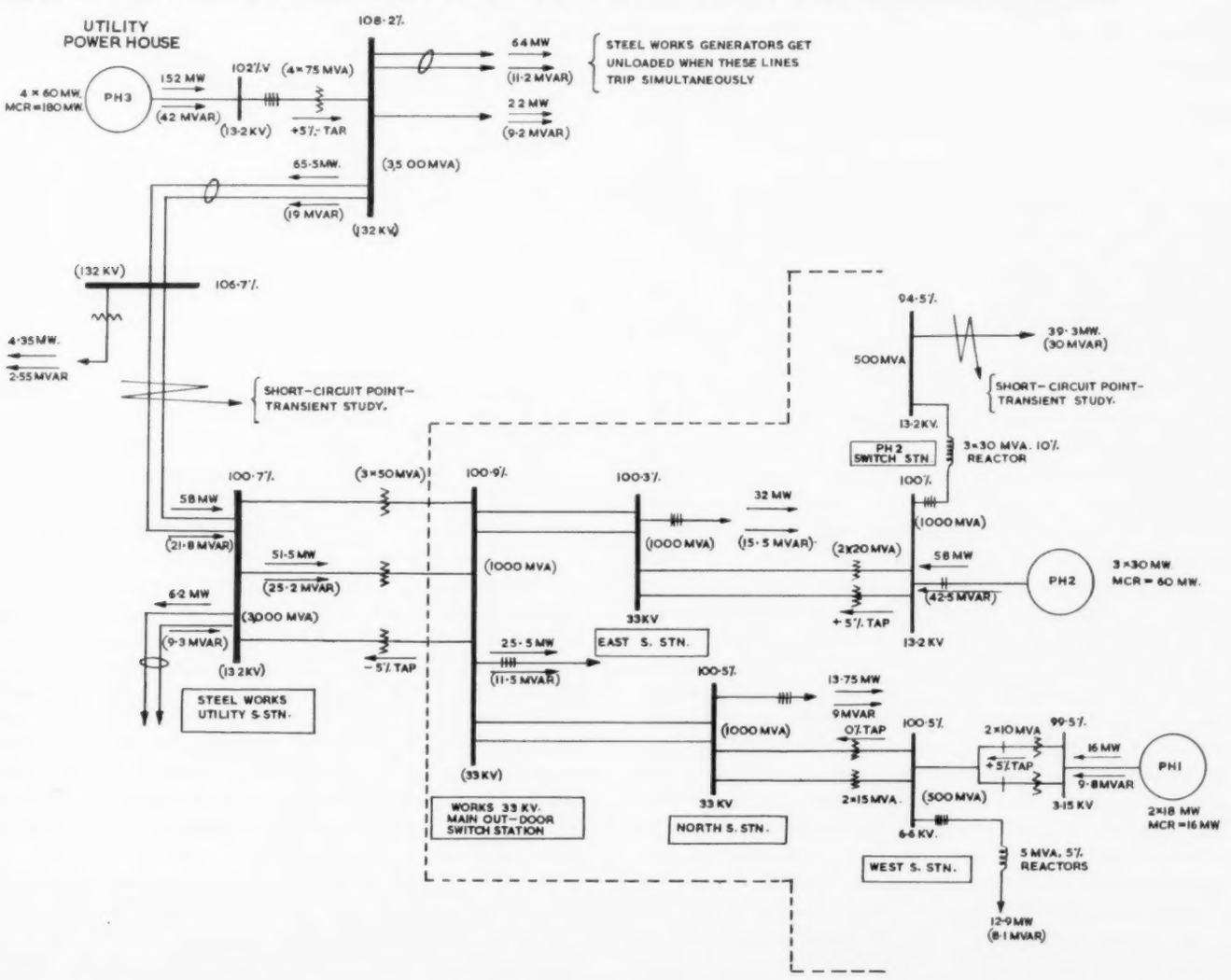
The study in Figure 2 shows that under normal conditions with three machines always in service in the works powerhouses, the normal imported power demand would be 51.5 mw and 25.2 mvar. The normal payable maximum demand therefore need not exceed about 57 mva. This is about 65 per cent of the contract demand. The analyzer study was made on the basis of maximum possible loading of the works generators. As the minimum payable demand at 75 per cent of 90-mva contract demand would be 67.5 mva, there is thus the possibility of drawing more mva from the utility system in order to reduce heating of the works generators.

The network analyzer study therefore provides valuable information not only on the system operation but also on the most economical contract demand for the power supply agreement.

To ascertain the steady-state stability, it is also necessary to compare turbine characteristics, as load sharing between turbogenerator sets would depend on the sensitivity and droop characteristics of the turbine governors. When a comparatively low-capacity industrial power station operates in parallel with a large utility system as shown in Figure 2, load sharing conditions between the two systems should be carefully studied to provide proper protection and control of the works generating machines. In Figure 2, the conditions are such that the utility powerhouse PH3 load is shared almost equally between the steel works system and other consumers. The experience with this system showed that, once when the double-circuit 132-kv lines outgoing from the utility system PH3 simultaneously tripped off due to direct lightening stroke, the fault created a heavy voltage disturbance resulting in the trip out of many machines in the steel works, while simultaneously the steel works turbogenerators dropped their load completely and reversed in operation. The steel plant load at the instant was wholly transferred to the utility PH3 which remained stable. The steel works generators at PH2 were provided with reverse power relays which operated in the case of one machine which was then disconnected from the system on reverse power. The other machine did hang on and slowly stabilized at about 3 mw.

This experience showed that the steel works machines tend to lose their load if there is a sudden heavy load drop on the utility powerhouse. The reverse power relays should then be connected for alarm circuit only, so that the generators do not trip off under such emergency conditions. It is thus advisable that the steel plant turbogenerators when operating in parallel

Figure 2 — An a-c network analyzer study was made to determine the kw and kvar at peak load conditions.



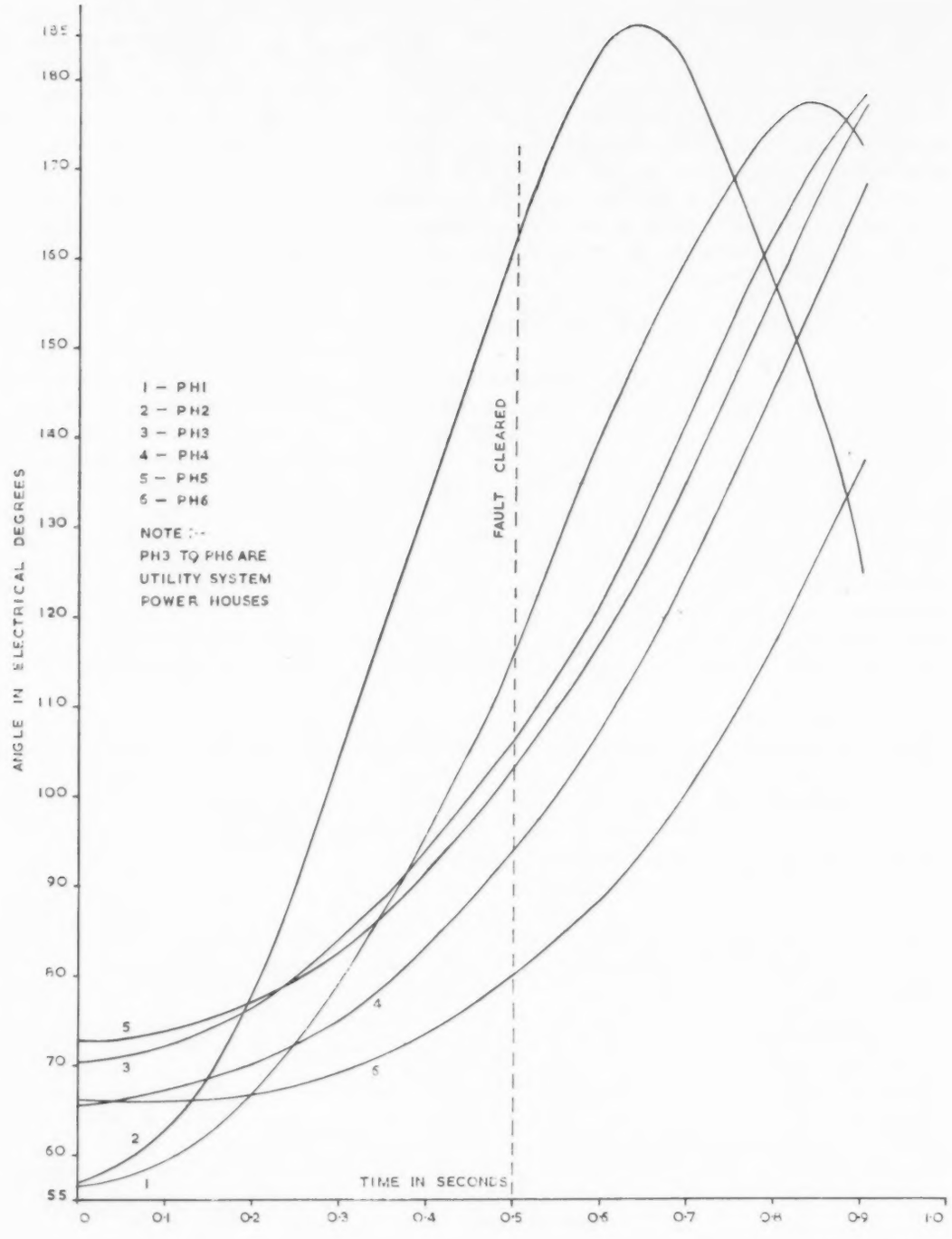


Figure 3 — Studies indicated that the plant generators maintained stability if a fault on the 13.2-kv bus at one of the plant powerhouses (PH2) was cleared in 0.5 sec or less.

with a large utility system are not provided with reverse power relays for trip circuit.

Steam turbines are always equipped with emergency steam closing valves which are operated automatically or by hand in the event of turbine overspeed, damaged bearings, etc. Furthermore, it is necessary to provide simultaneous tripping of the alternator breakers so that the set can be brought to stand-still. In order to prevent the turbine from running away, the alternator must not be disconnected from the system before the steam supply to the turbine has been definitely shut off. A safe criterion for this is reverse power taken from the bus bars. If a reverse power relay is employed in such cases to trip the alternator breaker, this relay should be connected through a contact at the emergency steam closing gear to prevent undesired tripping in the event of instability.

TRANSIENT STABILITY

A study of the transient stability of the system as a whole should also be carried out on the a-c network analyzer. The system in Figure 2 has eight powerhouses, interconnected over long distance 132-kv transmission lines. The transient stability study was made from view point of the works generators in this case. It can be judged that the severest fault condition would be a 3-phase short-circuit on the 13.2-kv bus of works powerhouse PH2, or a 3-phase short-circuit on 132-kv tie-line between the utility powerhouse PH3 and the works main receiving station.

In Figure 3, the transient stability results are shown for a 3-phase fault on the 13.2-kv bus bars at works powerhouse PH2. The fault is taken on 13.2-kv bus bars after the current limit reactor at PH2 which

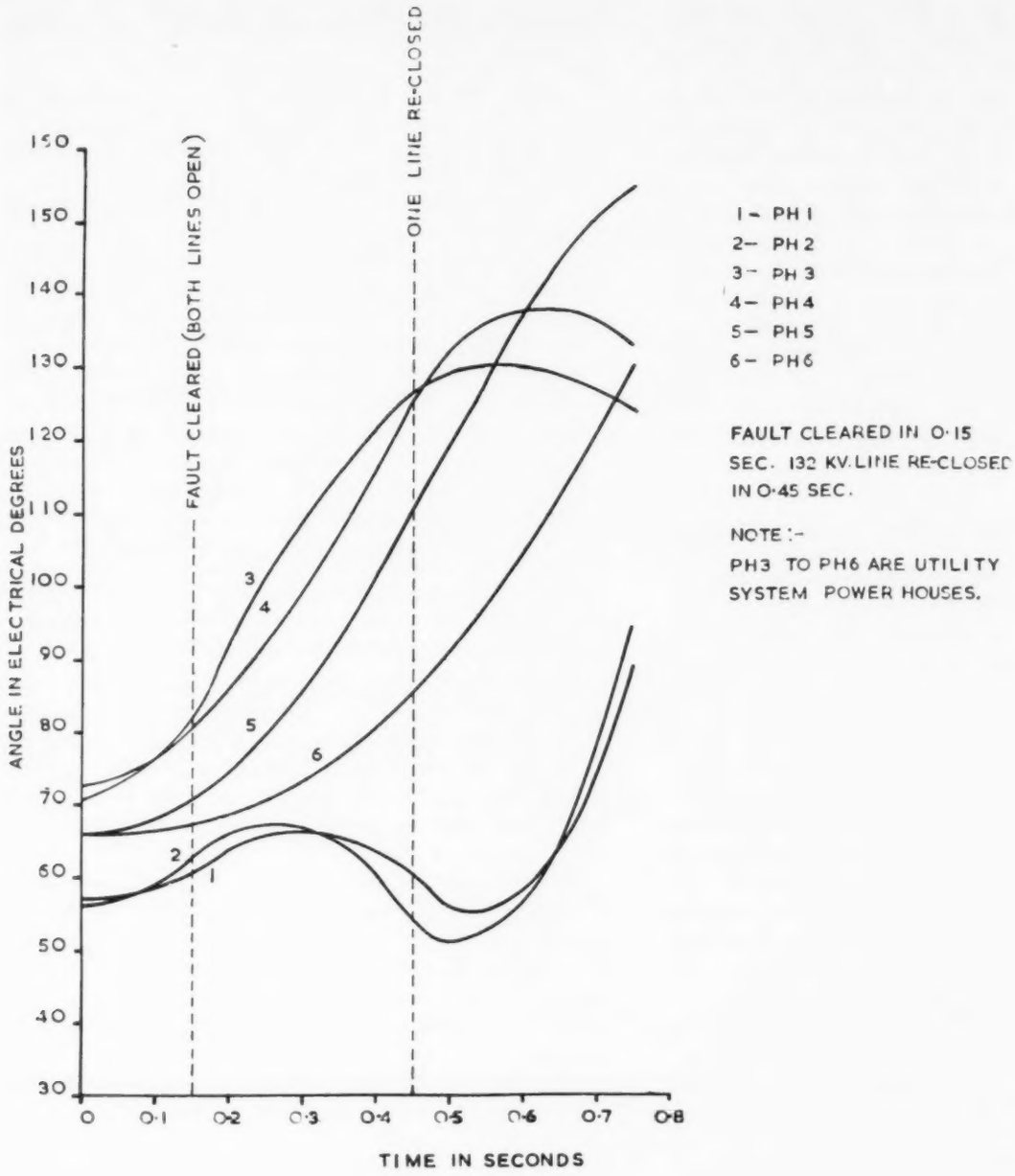


Figure 4 — If a fault on the 132-kv utility feeder is cleared in 0.45 sec or less the distribution system remains stable.

drops about 30 mw on fault clearance. The fault is assumed to clear in 0.5 sec. It will be observed that all the generating machines maintain their synchronism if the fault is cleared within 0.5 sec. The system has therefore to be designed for 0.5 sec limiting time. The circuit breakers and the relays at the 13.2-kv main switchboard of the works powerhouse PH2 shall therefore be selected for operation in a total time of 0.5 sec as a limit. The modern industrial-type circuit breakers could therefore safely be used for this system.

For a fault on 132-kv tie-line between utility and works system, the stability study is shown in Figure 4. For this study, it was assumed that both the 132-kv lines opened simultaneously on fault, while one line was allowed to reclose. The fault was assumed to clear in 0.15 sec and one line reclosed after 0.45 sec of the inception of the fault. This gives a reclosing time of 0.3 sec for the 132-kv circuit breakers. In the study, the two systems are assumed to remain separated for 0.3 sec. The study shows that the system is stable up to 0.45 sec after the fault, and it is possible to safely reclose the 132-kv lines. The system under study operates at 50 cycles.

When the power is received over one double-circuit feeder, it is advisable to provide auto-reclosing of the utility tie-lines to give maximum continuity to the steel works power supply. In the case under study, auto-reclosing was introduced on the utility 132-kv double-circuit tie-lines at each sectionalizing point.

When both the 132-kv tie-lines open simultaneously, it will be observed that the two systems separate with the result that all the steel works load is imposed on the two works powerhouses, PH1 and PH2. These machines thus are heavily overloaded and begin to decelerate as shown in Figure 4, curves 1 and 2. The problem has therefore to be studied further to determine the effects on the works system in case the 132-kv breakers fail to reclose at all.

Under such a situation, the works machines will keep decelerating, depending on the total load on the works system at the moment. The rate of deceleration will depend on the inertia of the turbo sets and the capacity of the boilers to provide steam as required.

In Figure 4, it is observed that the machines of

powerhouse PH2 control the system frequency. The frequency-time characteristic of the PH2 machine under the assumed overloading is shown in Figure 5. The calculations are made on the assumptions that the boilers steam generation as well as load conditions on the works system remain steady throughout the test. It is calculated that the frequency drops to 48 cycles in about 1.46 sec and to 47 cycles in about 2.07 sec.

For the security of the plants, it is therefore very essential that some provision is made for automatic load shedding on the works system under an emergency when the works powerhouses become separated for any reason, while the load conditions are such that, either one or both of the works powerhouses get overloaded resulting in drop of frequency to dangerous values.

EMERGENCY LOAD SHEDDING

The method of load shedding best suited is based on the drop of frequency of the generating machines. Sensitive, instantaneous, adjustable-frequency relays are provided at each vital station on the works system. These relays operate multi-point auxiliary relays which trip the selected circuit breakers to shed the system load when the frequency drops to the preset value. For maximum continuity of operations, the load shedding could be carried out in three stages, depending on the extent of overloading of the works powerhouse. The following has reference to 50 cycles as the tests were carried out with 50-cycle machines.

First-stage load shedding—The first-stage frequency relays are adjusted to 48 cycles. When the frequency drops to 48 cycles, these relays operate instantaneously to trip the selected feeders. During this stage of load shedding, depending on the works system interconnections, the following plants in the different locations are switched off:

1. All the motor-generator sets of the reversing rolling mills: the blooming and slabbing mills, reversing rail, structural and billet mills, plate mills and cold strip mills.
2. Electric arc furnaces and various maintenance shops.
3. Sinter plants and other auxiliary works feeders.
4. All the 33-kv step-down transformer feeders of the utility system. The frequency relays should be directional so that the switches will trip off over the frequency relays only when power is fed into the utility system from the works system.

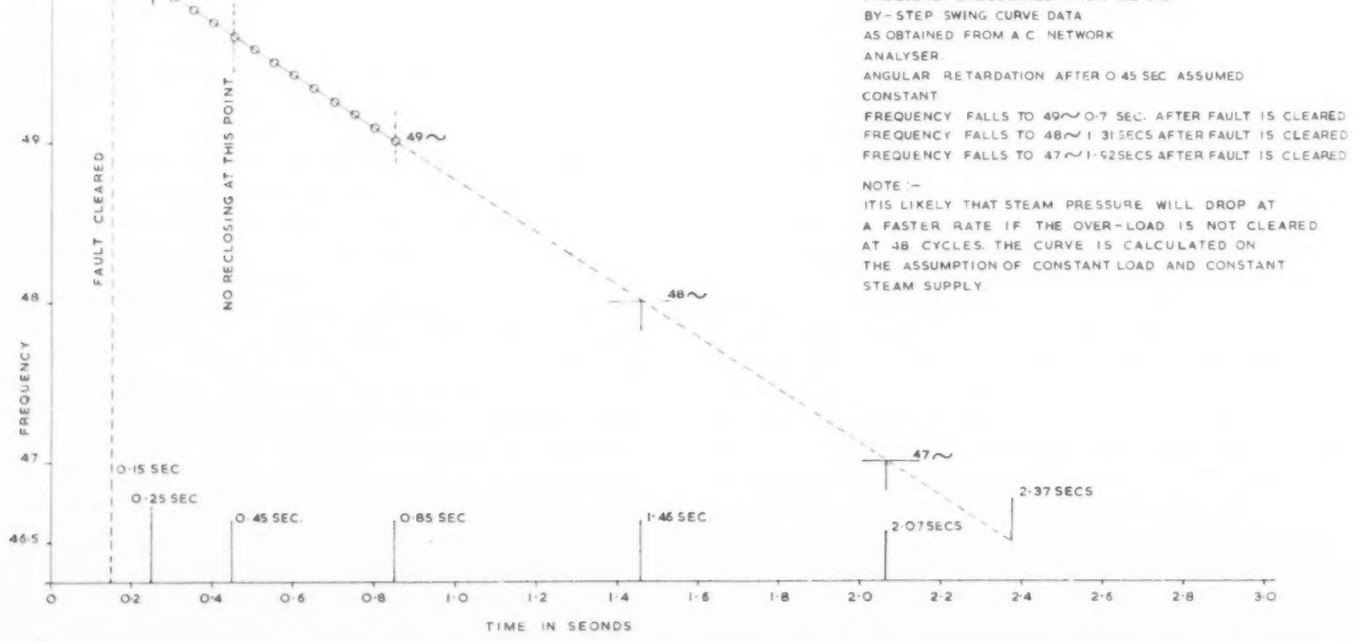
Second-stage load shedding—The second-stage frequency relays are set for 47 cycles which will permit further load shedding if the system frequency drops further to 47 cycles. During the second stage of load shedding, the following plants are switched off:

1. Continuous structural and billet mills, continuous merchant product mills and hot strip mills.
2. Duplex converter blower motors.

Third-stage load shedding—If the frequency of the system tends to drop still further even after the second stage of load shedding and the frequency drops to 45 cycles, the tie-lines paralleling the works powerhouses will open which would isolate the powerhouses and permit each powerhouse to operate with its own vital auxiliaries.

With the conditions assumed in Figure 2, the works system frequency drops to 48 cycles within about 1.45 sec as shown in Figure 5, when the first-stage load shedding is effected. The major portion of the load, about 80 mw, will be removed at 48 cycles which would stabilize the generating machines and prevent further

Figure 5 — If the 132-kv utility feeder fails to reclose, the plant generators will decelerate under the extra load and the frequency will drop to a dangerous value.



drop in the frequency. The second and third stages are provided in order to further safeguard the power system, in case all the loads set for the first-stage trippings do not clear.

The continuous mills are intentionally set for the second stage of load shedding. This would reduce the disturbance and also the delays to restart the plants when the power is restored.

The most essential auxiliaries, such as power plant services, steel plant cooling and condensing water system, are retained permanently in operation. The absolute minimum essential service load which shall be retained in operation for the plants in Figure 1 is estimated at about 15 mw. The works generation is ensured for at least 20 mw and the works distribution system is so planned that the most essential services are connected directly to the works powerhouses.

Actual experience with the system has fully justified the method of automatic load shedding adopted. The system had stabilized immediately after the first-stage shedding operations at 48 cycles, in two instances when the utility system and works system were accidentally separated.

For most steel plants therefore, it would be possible to stabilize the works system immediately after the first stage of load shedding. The limit of 45 cycles for a 50-cycle system is considered as the lowest safe limit of frequency for proper operation of the power station auxiliaries.

For a 60-cycle system, the frequency may be set at 58, 57 and 55 cycles respectively.

SYSTEM RELAYING

Stability of electrical operations depends greatly on the relaying of the system as a whole, so that the faulty sections are eliminated from the operations before the disturbance could spread further. It is therefore essential that the relays are selected and adjusted after a thorough study on a network analyzer, based on the short circuit currents at different locations.

The short circuit ratings indicated for each station in Figure 2 were fixed after a thorough system short circuit study. It will be observed that the works feeders at 13.2 kv and 6.6 kv, emanating from the stations at the works powerhouses PH2 and PH1 respectively, have current limit reactors. These reactors limit the short circuit current in those outgoing feeders, which reduces the shock on the system and increases the stability to a great extent. They also help in the economy of the switchgear cost at the receiving substations. The cables directly connecting the generator bus were all selected as fully insulated single-conductor cables, laid in trefoil formation on insulated cleats to minimize the possibility of short circuits directly on the generator bus, as such short circuits become critical for transient stability of the machines with industrial circuit breakers.

For most effective relaying, it is desirable to provide a 2-stage relaying system, namely, instantaneous relays backed up by sequential time-delay relays for each feeder. Experience has shown that the most effective selective relaying system can be provided, if the following positive aspects are carefully introduced.

1. All major electric stations shall have full capacity duplicate feeders so that the maximum power flow is ensured even if the largest feeder goes out of service.

2. All major stations shall have sectionalized full capacity bus bars, interconnected over full capacity bus-section circuit breakers which could be operated under all conditions.

3. The system neutral shall be grounded such, that transient over voltages are suppressed under all switching and fault conditions, and the ground fault current is limited to a maximum up to the full load current.

4. Each major feeder shall be relayed with fast acting pilot-wire relay protection, backed up by definite minimum-time inverse-current overload relay protection. No instantaneous short circuit current relay shall be provided on the main power feeders.

5. Parallel feeders shall have directional protection at the receiving end as extra protection for selective tripping, if a fault in one of parallel feeders is not cleared instantly due to failure of the pilot-wire protection.

6. Each bus-section switch shall be relayed so that, if an outgoing faulty feeder switch fails to trip, the bus-section switch will open before any of the incoming feeder switches open. This will permit a closed-circuit system to be suitably sectionalized to prevent a total power failure.

7. All switchgear below 15 kv shall have fully insulated bus bars with all connections insulated to prevent possibility of ground faults. All 33-kv bus bars shall have bus-zone protection, with two relay systems in series, one bus-zone relay system backed up by the other bus-zone relay system. This will prevent power failure due to faulty operation of any one bus-zone relay system. All 33-kv enclosed-type switchboards shall also have fully insulated bus bars.

8. All equipment feeders, along with other essential relays shall also have instantaneous overcurrent trips with current adjustments of 6 to 12 times the full load current rating. This would give the selective instantaneous protection on severe short circuit faults. The ground fault relays shall be set for at least 15 per cent full load current and shall also have an instantaneous current trip in each phase. This would permit fast selective tripping depending on the magnitude of the fault current, with minimum of damage to the faulty equipment.

9. All equipment feeders shall have time delay under voltage protection. The under voltage relay should be of induction type with inverse-time characteristics. The minimum definite time delay at zero voltage should preferably be set for 0.3 sec, and about three sec when the voltage drops to 70 per cent of the normal. No under voltage protection need be provided on the main power supply feeders, either at the sending or at the receiving end. This precaution is essential to restore the power supply with the least delay, as in that case the main power will be readily available on the bus after a power failure, and only the equipment feeders will be required to be re-energized.

10. In the past, it was a general practice to provide duplicate bus bar-type switchboards with bus-change-over isolators to ensure continuity of power in case of failure of one bus bar system. With the advent of the modern industrial switchgear with fully insulated bus bar systems, there seems no need to complicate the

switchboard with a double-bus system with its inherent complications of isolators and interlocking for correct isolator operations. The modern practice of providing distributed duplicate feeders and sectionalized bus bar switchboards gives maximum safety of operations and ensures the continuity of power supply without the complications of a duplicate bus bar system.

In the case of higher-voltage, outdoor installations, the double bus bar system may be adopted.

STABILITY OF ELECTRIC MOTORS

A-c motors are subject to stability limits under actual operating conditions, as the operating characteristics of these motors depend on the voltage and the pull-out torque for which the motors are designed. The pull-out torque of an induction motor varies as the square of the voltage, whereas that of a synchronous motor varies directly as the voltage.

During a power system disturbance in a plant, when the base voltage tends to drop down, motors at various locations drop out of service, depending on the magnitude of the voltage drop, the duration of the disturbance and the load characteristics of the driven machines. Fully loaded constant torque drives are more dependent on the system voltage than the drives for which the torque reduces when the speed goes down.

The most troublesome aspect of the plant operations with a-c electric motors lies in the fact that the operations are disturbed at diverse locations whenever there is a voltage disturbance due to the electric system faults.

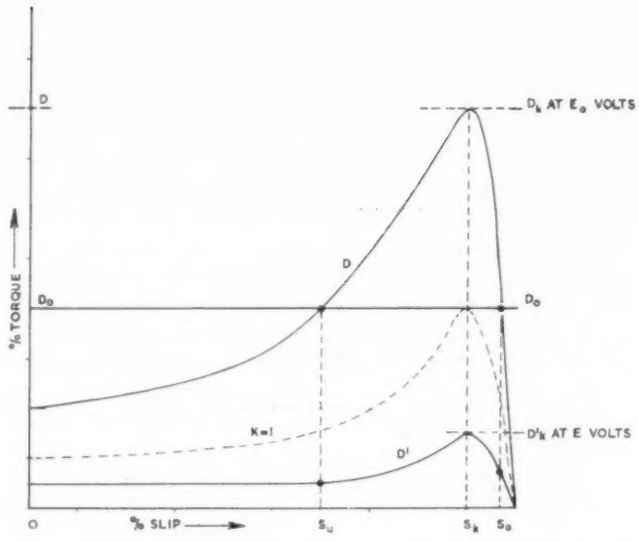
To reduce such stoppages, it is essential that the motor designers as well as the control designers study the specific operating problems and incorporate means which permit continuity of service within specified limits.

Experience shows that for steel plants, it would be desirable to provide the stability limits as follows:

Transient voltage, 0 per cent....0.2 sec duration
Transient voltage, 50 per cent....0.7 sec duration
Transient voltage, 70 per cent....2.0 sec duration
Voltage, 85 per cent.....Continuous operation

The motor drives should therefore be engineered both with regard to pull-out torque and protective control, so that they maintain the operation under system disturbance conditions as specified. From the view point of economy, only the most essential drives, which may cause a complete stoppage of the operations, need be provided with such stability features. Less important drives, which could be safely restarted after a disturbance, should be allowed to trip out, so that the electric system load is reduced in order to stabilize the plant generation at the quickest rate after the disturbance is eliminated.

Induction motors—Induction motors are sensitive to voltage drops as their pull-out torque varies as the square of the voltage. If the voltage drops to 80 per cent, the pull-out torque of the motor drops to 64 per cent. With a standard induction motor with 180 per cent pull-out torque, this would be reduced to 100 per cent when the voltage drops to 75 per cent. It would therefore be appreciated that an induction



CURVE D — SLIP-TORQUE CURVE FOR NORMAL VOLTAGE
CURVE D' — SLIP-TORQUE CURVE FOR LOW VOLTAGE
D_k — NORMAL PULL-OUT MOTOR TORQUE
D_0 — FULL-LOAD TORQUE OF THE DRIVE
S_0 — NORMAL FULL-LOAD SLIP
S_k — SLIP AT PULL-OUT TORQUE
S_u — LIMITING SLIP AT LOW VOLTAGE

$$K = \frac{D_k}{D_0}\left(\frac{E}{E_0}\right)^2$$

Figure 6 — Induction motors are sensitive to voltage drops for their pull-out torque is a function of the square of the voltage.

motor with 180 per cent pull-out torque would reach its stability limit at 75 per cent of its base voltage if it is fully loaded.

In Figure 6 are shown the slip-torque characteristics of an induction motor. The curve D represents the normal operation, while D′ represents the operation at a lower voltage. If it is assumed that in case of a short circuit, the voltage drops from E_0 to E and the motor torque drops from D to D′, the relationship between voltage and torque is given by:

$$\frac{D'}{D} = \left[\frac{E}{E_0}\right]^2$$

If full load torque is D_0, the relation between D and D_0 is given by:

$$\frac{D'}{D_0} = k\,\frac{2}{(s/s_k) + (s_k/s)}$$

where s represents the slip of the motor at the respective torque values and:

$$k = \frac{D_k}{D_0} \times \left[\frac{E}{E_0}\right]^2$$

At reduced voltage, the motor tends to drop in speed as shown in Figure 6. It is therefore necessary to estimate the time taken by the motor to drop to the lower speed relative to the voltage drop. If s_k is the

slip at maximum torque D_k, T_a is the motor accelerating time in sec, and t_1 is the time taken for the drop in speed, the limiting time t in sec is given by:

$$t = s_k \times T_a \times t_1$$

In Figure 7, the relationship between E/E_0 and t_1 is indicated for the different pull-out torque values of an induction motor. For a motor with 200 per cent pull-out torque, $D_k/D_0 = 2$, it will be seen from Figure 7 that with $E/E_0 = 50$ per cent, for a 50 per cent voltage drop, $t_1 = 5.7$. For a motor having ten per cent slip at pull-out torque and an acceleration time constant of one sec, s_k = ten per cent, T_a = one sec and t_1 = 5.7 sec, the limiting time for which the motor can remain stable for the 50 per cent voltage drop is calculated by:

$$t = \frac{10}{100} \times 0.1 \times 10 \times 5.7 = 0.57 \text{ sec}$$

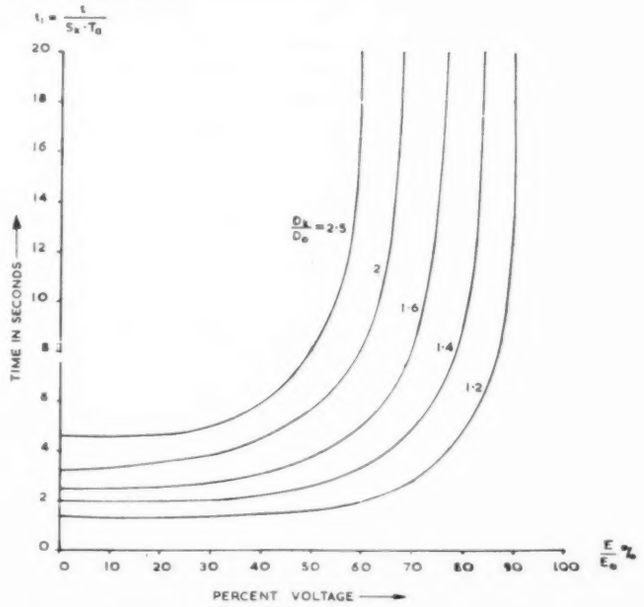
The above calculation shows that for an induction motor with a pull-out torque of 200 per cent, if the voltage drop of 50 per cent is sustained longer than 0.57 sec the motor will pull out of step and will not be able to reaccelerate on return of the voltage. If the short circuit is such that the voltage goes down to zero, the time limit is reduced to about 0.35 sec.

For maximum stability therefore, induction motors for all vital services shall be designed for at least 200 per cent pull-out torque. For drives which are normally fully loaded, it is desirable to design the motor for 250 per cent pull-out torque.

From Figure 7, it will be observed that for 250 per cent pull-out torque motor, the permissible time limit for zero voltage will be about 0.4 sec, and for 50 per cent voltage it is 0.8 sec. A 250 per cent torque motor will therefore always remain stable for the limits specified.

If the induction motor is designed for full-load starting, it will reaccelerate even from transient zero voltage. The accelerating current peak when the voltage returns, will depend on the short circuit impedance of the motor. The overload current setting of the motor shall therefore be set such that the motor is allowed to reaccelerate without any premature tripping due to over current.

Figure 7 — The greater the pull-out torque rating, the longer the motor can maintain stability at greatly reduced voltages.



With a slip ring induction motor operating with short-circuited slip rings, the current peak may reach as high as 10 to 12 times the motor full-load current. Such motors therefore may get overheated during reaccelerating on voltage return, and normally are relayed out by the over current protection, unless the motor slip ring control is designed for automatic reacceleration over the secondary resistance control.

Slip ring motor control—Slip ring induction motors have the inherent advantage that they permit speed control below synchronous speed and provide good starting characteristics over the secondary slip ring resistance control without high starting currents. The motor maintains its peak torque irrespective of rotor resistance. Slip ring motors are therefore used whenever large size motors are required to be started on full load.

For the steel works in Figure 1, the circulating water system was a central cooling pond, recirculating system. All the service water as well as the turbine condensing water was pumped through a cooling pond pump house. The pumps were 1000 hp and 600 hp designed for 3000 volts. The motors were all slip ring induction motors with hand-operated, oil-immersed rotor resistance starters with slip ring short-circuiting devices.

Whenever there was a heavy fault on the power system resulting in a voltage dip, the pump motors tripped out creating a serious interruption in the water system service. It was observed that the motors were tripping mostly after the fault clearance, when the system voltage recovered to normal. This was attributed to the heavy current drawn by the slip ring motor on voltage return when running with shorted slip rings.

To eliminate this trouble, the pump house control was completely replaced with a special auto-cycling, slip ring, magnetic secondary motor control. This control is shown diagrammatically in Figure 8.

The existing motors had a pull-out torque varying from 180 to 200 per cent. The new control was so designed that when the system voltage dropped to a preset value for a sustained period of 0.2 sec a sensitive voltage relay operated and introduced the motor secondary resistances into circuits. As soon as the voltage returned to about 90 per cent, the secondary control resequenced and the motor reaccelerated to its normal condition.

In Figure 8, the voltage relay UV is connected to the 110-volt a-c potential supply from the potential transformer of the high voltage stator switch of the motor. The relay UV pulls in at 99 volts and drops out at 82.5 volts. The drop-out voltage is adjustable down to 55 volts.

As soon as the motor stator switch is closed, the motor is connected to the high-voltage power with full resistance in the rotor circuit. Closing of the stator switch energizes the voltage relay UV which in turn energizes the auxiliary relay 1R. Closing of contactor 1R starts the accelerating relay AR which then initiates the secondary resistance sequence over its time-sequenced contacts, until the last step contactor 3AC

closes (3AC is a latched-type contactor with a 440-volt closing coil and a 48-volt d-c tripping coil). The control has essential safety sequential interlocking for correct operation, and a 48-volt battery ensures a constant, stable trip power.

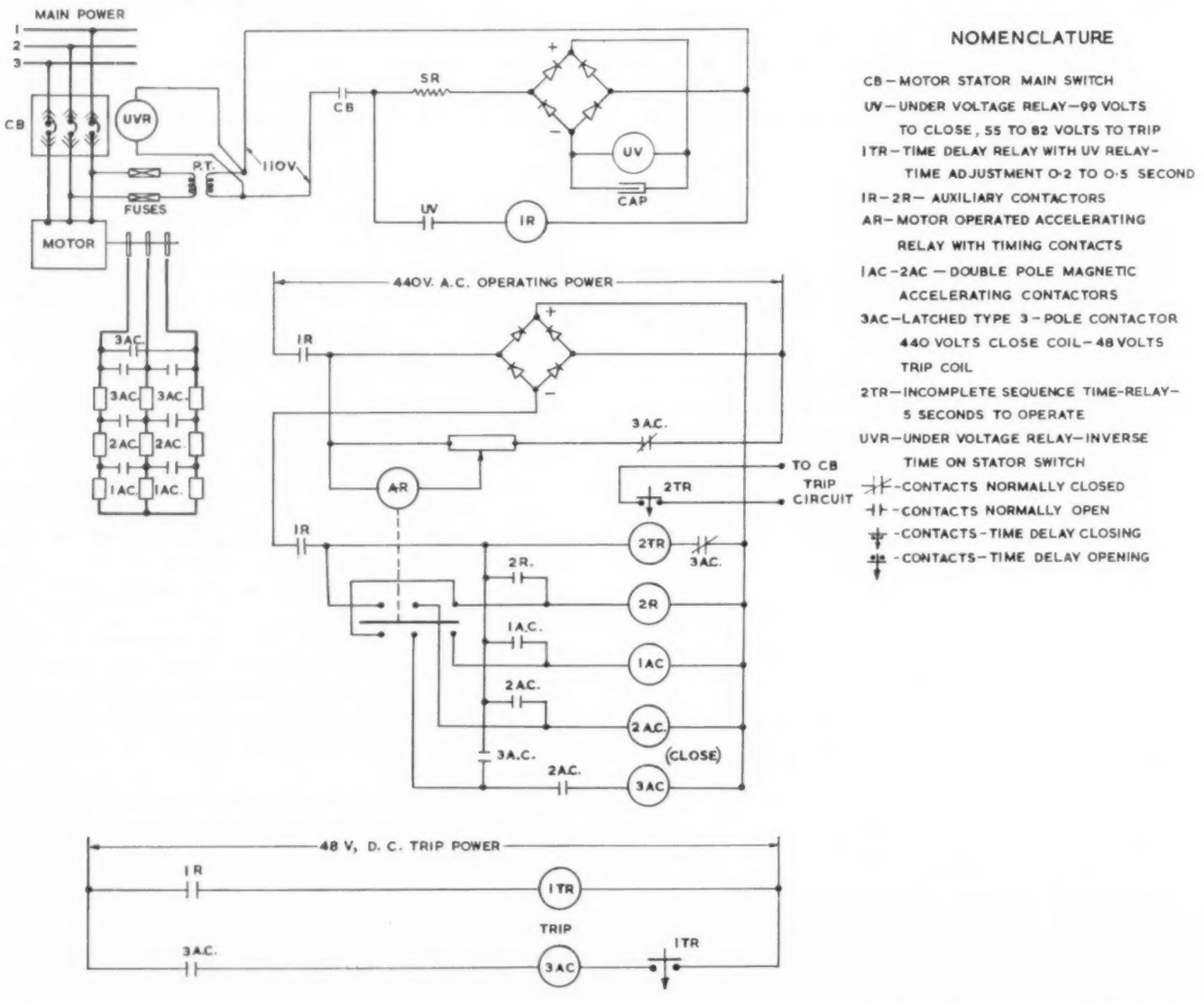
The voltage relay UV operates a time-delay relay 1TR set for 0.2 sec to close its contacts when de-energized. This time delay prevents the cycling of the controller during instantaneous transient voltage dips. When the voltage dip persists at least for 0.2 sec and the voltage drops to 80 per cent, the relay UV drops out and opens the motor secondary resistances after 0.2 sec. The relay UV recloses when the voltage returns to at least 90 per cent of the normal and resequences the motor secondary control. This provision is provided so that the acceleration contactors close on positive voltage in order to prevent freezing of contacts on closing at full current and reduced contact pressure. The secondary resistances are designed to carry full-load current for five min. If the voltage remains below 70 per cent for three sec, the under-voltage relay on the stator switch operates and disconnects the motor from the line. If the latched contactor 3AC fails to close, the time relay 2TR operates after a fixed interval of five sec from the start, which opens the stator switch and disconnects the motor from the power. The stator switch can close only when all the three accelerating contactors are open.

Additional auxiliary contacts on 3AC and TR relays are connected to a central indicating and alarm panel which gives the selective indication and alarm for each motor control.

Operation of the pump house has stabilized and no disturbances to pump operations have been noted whenever there have been power system troubles. One of the most troublesome problems of stable operations was successfully corrected for the plant concerned, and it was found that the hydraulic pumps maintained suction during the period of all disturbances experienced on the power system.

Squirrel-cage motor control—The problem with the squirrel-cage induction motor lies in the fact that the motor causes a heavy current inrush while reaccelerating on voltage return. Where several large size motors operate together, the problem of simultaneous current inrush creates conditions equivalent to a short circuit. However, with individual motors, it is possible to provide a d-c coil-operated main contactor, where the oper-

Figure 8 — Redesign of the controls for the circulating water system pump motors permitted system operation during all periods of power system disturbances.



ating coil is connected in a circuit to provide time-delay tripping so that the motor can remain connected to the power supply for the duration of the voltage disturbance. All the auxiliary motors at 440 volt can have such pushbutton-operated contactor starters so that the motors remain in operation during the duration of the voltage disturbance.

Where several motors are concerned, it is possible to design the control so that the motors are disconnected from the power line and then reconnected on the return of voltage. The restart of the motors could be arranged in a staggered time sequence so as to prevent the simultaneous heavy current surges on the power system.

In Figure 9, a scheme of control is shown with a magnetic contactor starter, providing auto-reclosing, on the voltage return, of the starting contactor after a fixed time delay. The auxiliary contactor d has its coil paralleled over time-lag capacitor k, which holds the contacts d closed for a fixed time delay. The contacts d bridge the holding-circuit contacts c so that the coil c remains connected to the power lines for the time delay provided by the auxiliary contactor d. The time-delay setting for the contactor d can be adjusted over the resistance r in the parallel circuit. Time of restarting is staggered between different motor starters over the special timer TR which could be adjusted so as to give a short interval between the restarting of the different motors, in order to stagger the current peaks as the motors are automatically reconnected. The voltage relay UV ensures that the a-c contactor recloses only when the voltage returns to at least 90 per cent of the base value. The sequential reclosing control can be easily added to any standard contactor-type motor starter.

When a whole mill with many motors is concerned, it is preferable to provide a separate flywheel motor-generator set, which would supply an independent control power for the motors. The set has then to be designed for the voltage-time settings as specified previously. Such an arrangement will give maximum stability to the mill operations, as the control voltage will be positively maintained during the transient voltage disturbance and all the connected motors will re-accelerate on the voltage return.

Variable-voltage d-c drives—Where the continuous or semi-continuous mills with variable-voltage grid-controlled rectifiers or rotating amplifiers are concerned, the problem becomes rather difficult. Rectifiers are inherently voltage sensitive, as the d-c output voltage is always proportional to the a-c input voltage. The reference voltage and the excitation voltage stability is therefore very vital. For such mills, it is essential that the mill motor speed control is always provided with current limit control so that the motor can reaccelerate the drive automatically in a smooth manner when the voltage returns.

For the reference voltage of amplifiers and the excitation voltage of rectifiers, it is necessary to provide separate rotating exciter sets with flywheels. The flywheel will maintain the exciter speed and therefore the exciter voltage. For purpose of maximum stability of the mill operations, excitron rectifiers are preferable to the ignitron rectifiers. With the ignitron units, the ignition power has to be of the same phase as the main anode voltage; therefore, it should be from the same power source.

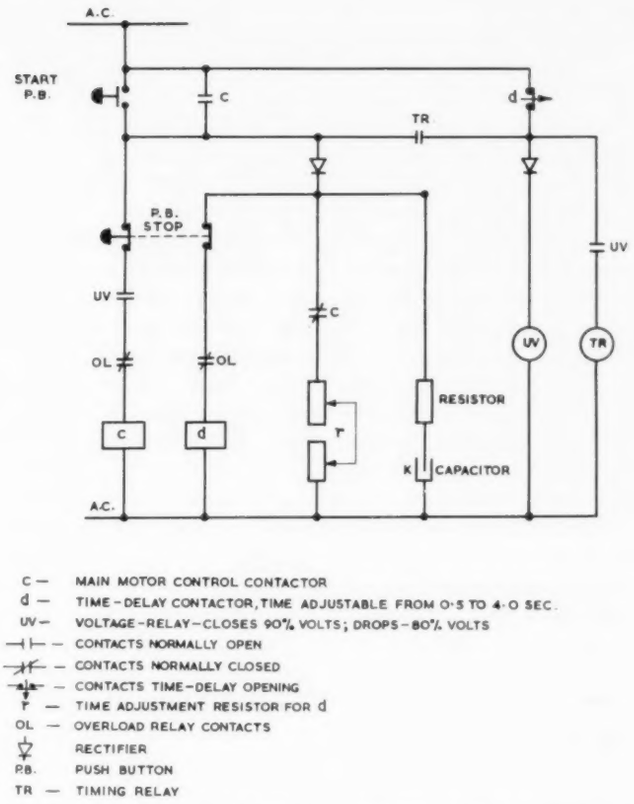


Figure 9 — Staggered time sequence automatic restarting of induction motors after transient voltage dips is necessary to reduce the instantaneous load which could be imposed upon voltage rise.

A rectifier-operated, continuous merchant product mill recently commissioned at the plant in Figure 1, is provided with all the above mentioned features, which have proved themselves in practice. This mill always remains stable, while similar older mills come to a stop due to the tripping out of the rectifiers and motors at times of severe transient system disturbances.

Synchronous motors—Synchronous motors with leading power factor excitation are inherently more stable under voltage disturbances provided the motor excitation is not simultaneously disturbed.

The modern self-starting, self-synchronizing synchronous motor, designed to start on full load, provides a stable drive for steel plant loads. Where a constant-speed drive is required and where system power factor correction requires an over-excited motor, a synchronous motor becomes an ideal drive.

For steel plants, the synchronous motor should be designed with a squirrel-cage rotor winding with increased heating capacity, so that the motor can carry the load for the specified time of the voltage dip if the motor falls out of step. A modern slip-cycle, auto-reclosing synchronous motor control allows the motor to re-synchronize on load on voltage return, in case the voltage disturbance has been of such a magnitude that the motor falls momentarily out of step and operates as a squirrel-cage motor during the transient disturbance.

For main mill drives, the synchronous motor is designed for at least 300 per cent pull-out torque. For other constant speed drives, the motor pull-out torque should be at least 250 per cent. The magnetic contactors and relays used for the motor control must also be de-

signed so that they do not drop out suddenly during the transient voltage disturbance.

SPECIFIC CONSIDERATIONS OF SYSTEM PLANNING

In recent times, the great advances in the design and development of magnetic amplifiers, transistors and silicon rectifiers have almost revolutionized the control technique in industrial applications. Within a few years, it will be possible to provide completely static contactless electrical controllers for most industrial applications, to the extent that the electrical motor would perhaps remain the only moving and rotating element, while all other operations would be performed automatically with the use of static rectifiers, magnetic amplifiers, transistors, etc., which will provide the motive and control power, while thinking would be done by computors, television units, photo-cells and other electronic devices.

Even for steel plants, more and more factory-engineered and completely factory-assembled electrical equipment will be used, when the customer will be required to supply only the connections for the power supply and wiring to the driving motors. The maintenance would mostly be checking the circuit operations, by means of instruments and annunciators which would indicate the possible faults during troubleshooting. Fault curing would then be done by a complete replacement of a compact unit, which could be either thrown away or returned to the manufacturer for replacement repairs.

In spite of such advances, the efficient operations of the plants will invariably still depend on an equally efficient, stable and well planned power generation and distribution system. Industrial power distribution systems, especially for the present day, huge, integrated steel plants, present problems which could be solved only by an equally integrated and co-ordinated approach by power system engineers, motor designers and control system engineers.

This article is an attempt at presenting the various diverse problems that must be considered if a stable and efficient electrical system is to be provided. The problems discussed and the remedies suggested have been the results of actual application in a large integrated steel works, which grew over a period of half a century under rather difficult conditions in an underdeveloped country. This plant was recently expanded to double its previous capacity, necessitating fundamental modifications to the then existing power system to permit its incorporation into a vastly enlarged system.

In order to obtain the best system possible, certain specific planning recommendations should be followed. These recommendations are:

1. Make a thorough study of the power system on an a-c system network analyzer from all possible aspects: power flow study, transient stability study, short circuit study and relay study.
2. Plan the power distribution in such a manner that the most vital plant services are connected directly to the works powerhouses so as to ensure maximum continuity of power supply.
3. Plan the system on the basis of firm power capacity of each major station so that the maximum power flow is ensured even if the largest feeder goes out of service.
4. Plan the system such that it could be sectionalized automatically as needed in an emergency. The system should however be capable of operation as a closed system.
5. Provide a comprehensive relaying system with quick-acting, selective relays, properly rated circuit breakers and modern factory-assembled, fully-insulated, oilless switchgear.
6. Provide a comprehensive system of telemetering and supervisory remote control of the major substations, so that a centrally located load-dispatcher could control and operate the system in an efficient manner.
7. Pay maximum attention to the selection and design of vital mill motors and controls so that maximum stability of operations is maintained even under severe system disturbances.

The problems faced in the operations and maintenance of the electrical plants and equipment in a modern steel works are extremely diverse and complicated, and always present challenges to one's ingenuity and experience. The complete automation of steel plants in the near future presents a fascinating aspect to engineers and will lead the industry to greater heights of efficiency and perfection. ▲

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SUPER-LATHE FOR ROLL TURNING

by JACK BINNS
Owner
Binns Machinery Products
Cincinnati, Ohio

. . . . lathe structural rigidity is an important factor in the utilization of full horsepower during roll turning, regardless of the roll material or the type cutter used . . . .

DO not scoff at a piano rest! Those who build tracing lathes face facts and admit that form turning on a piano rest is still the most economical method to produce certain shaped contours. Even though it is well over 100 years old, the piano rest still commands a respectable place in the industry. During that same hundred years, all the rest of the metal cutting processes have changed many times, even to the point where obsolescence has consecutively occurred in just a few years. To account for the longevity of the piano rest, it is only necessary to look at the fundamental principles upon which it operates. They are inherent simplicity and extreme rigidity: almost no moving parts, very few joints and all forces (actions and reactions) very closely coupled.

Axiomatically, the same fundamental principles apply today just as they did 100 years ago: they will continue to apply for 100 years to come. They apply to all metal cutting machinery, even the contour tracing roll lathes, which is the principal topic of this article.

The application of these principles to a tracing lathe is illustrated by the ensuing examples, which are specifically directed toward the machine shown in Figures 1 and 2. This machine has a capacity of 22 in. in diameter by 96 in. between centers, and is rated for continuous duty at 15 hp per rpm limited by a maximum of 75,000 ft-lb output torque at the spindle and/or 250-hp input to the headstock.

The bed of a lathe is its main structural member and must be designed to withstand the applied loads with a minimum of deflection. For the principal standards upon which all of the bed designs are based, the following criteria have been established: the bed alone, when supported as a simple beam at its extreme ends, will sag at the center of the span less than 0.0003 in. per ft of bed length as a result of its own weight; the torsional deflection of the bed, when standing free and subjected to the maximum rated spindle torque reaction, will be 0.000060 in. per ft of bed width per ft of bed length subjected to torsion.

To best meet such requirements, it is obvious that a material of high elastic modulus be utilized. To actually design the details of the bed, it is a relatively simple matter to feed in the pertinent data and turn the crank. The resulting structure is an elongated steel box, fabricated from hot rolled plate, wherein the six exterior plates of the box are the principally stressed members.

The strength of such a unit is tremendous. When subjected to maximum rated loads, they develop maximum unit stresses of not over 500 psi in the principally stressed members. Under these conditions, strength and vibrations are of no consequence. The philosophy used is to design for rigidity: if a machine is rigid enough to cut hard and tough rolls, it is also strong enough to cut softer rolls; if a machine is rigid enough so that it does not vibrate, there is no need to dampen vibrations. Therefore, the modulus of resilience of the material from which it is fabricated is not even a consideration, whereas modulus of elasticity is of prime importance. Hence, the use of steel for all structural members instead of cast or nodular iron, and wrought steel instead of cast steel.

The tailstock of the machine, as illustrated in Figure 2, continues the same type of thinking in its design as that of the bed: notice the rectangular quill. Its ability to take radial loads is two or three times as great, for any given amount of deflection, as the equivalent inscribed circular quill with an identical bore. The method for clamping the tailstock to the bed is also designed for maximum rigidity; it is roughly the equivalent of a homogeneous joint. When the three bar nuts at the bottom edge of the tailstock are pulled up with 75 ft-lb of torque, the force required to separate the tailstock from the bed is approximately 1,000,000 lb.

The headstock design is also treated similarly with

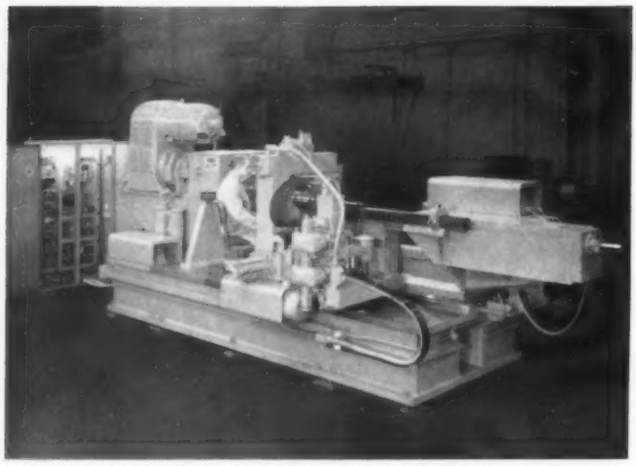


Figure 1 — Extreme rigidity of the lathe bed reduces the possibility of vibration during heavy cuts.

emphasis on rigidity. It is wrought steel, with each piece heat treated to give the best properties for its particular function. An example of designing for rigidity is in the power shafting, no shaft between gears is smaller in diameter than the length between those gears. The main spindle bearing, the bull gear and the ring gear are all the same nominal diameter as the maximum size of roll that the lathe will turn.

Throughout the entire machine, the same principles were followed. No item is too small nor insignificant to be considered. A slight improvement accumulated in each of a hundred different parts or joints becomes, as a whole, a substantial improvement. There must be no compromise in design, and equally important, the parts must be made and assembled according to that design.

A final and conclusive test for adequate rigidity of the entire machine and tooling, a test that must be passed by every machine built, is to stop the machine in a cut while tracing a templet and then start it again. If the cutter breaks, or if a noticeable mark is left in the finish of the roll at the point where the cutter was stopped, there is insufficient rigidity. On the super-lathe, this test is performed with both carbide and ceramic cutters. In the case of the ceramic cutter, a $\frac{5}{16}$-in. deep cut on the radius is used with 0.025-in. per revolution feed in a roll of 55 to 60 Shore containing 15 per cent cementite, an operation which requires a cut force of 2500 lb, more or less. Incidentally, these tests take into account the combined rigidity of the work as well as the machine and cutter. If the work is long and slender, it will itself lack sufficient rigidity between centers and must be test cut in housings.

The benefits derived from a machine designed and built to such stringent specifications are twofold. An immediate return is from its ability to machine in less time many of the rolls on hand in current inventories. In anticipation of future demands, it allows wide use of rolls that produce the most tonnage per dressing without the previous concern over the ability to machine the roll. In addition, it gives roll manufacturers more freedom to produce better roll alloys with less concern about machinability. An example of the capability of such a machine is shown in Figure 3. A 15-in. diameter medium hard roll with a 32-in. body and 72 in. between centers was reduced to 13-in. diameter in 19 min of cutting time. Also, a 13-in. diameter by 28-in. body roll, a very hard and tough rod mill roll, with an as-cast body was faced-off to size in 18-min cutting time with a cutter life of three rolls per cutting edge per grind. This operation formerly took $2\frac{1}{2}$ hr using carbide cutters.

Both of the preceding examples were performed with ceramic cutters and were ordinary in every respect, not at all spectacular, the kind of cut that can be reproduced with similar results each time. And, since the cut shown in Figure 3 is a good example of a practical roughing cut, the cutter from it was chosen to illustrate the typical ceramic cutter appearance found after each satisfactory cut. Figure 4 shows that cutter looking obliquely downward from the work side. The cutting edge is the edge closest to the scale and running from the end of the scale to the 2-in. mark. The chip on top of the cutter is in its proper relative position with a portion of it removed to show, beneath it, the top of the cutter adjacent to the cutting edge. The dark streaks, which are on the top surface of the cutter and perpendicular to the cutting edge, are characteristic and are left by the chip flow. The cutter was set at a 60-degree lead angle and fed at 0.035 in. per revolution with a cut speed of 190 fpm.

Ceramic cutter wear is much the same as that experienced with carbide cutters. The life of a cutting edge is determined by the portion that has been abraded

Figure 2 — The tailstock can be securely clamped to the bed.

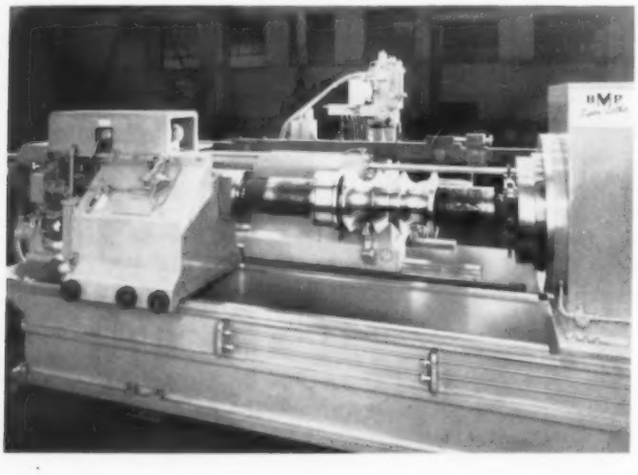


Figure 3 — Large roughing cuts can be taken using ceramic cutters.

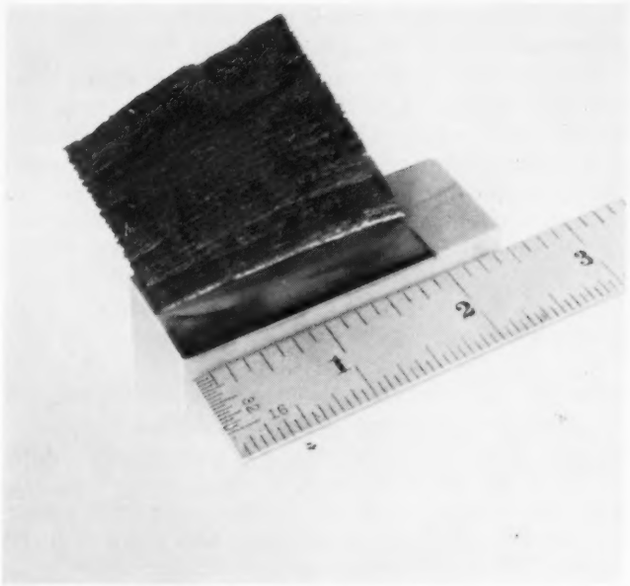


Figure 4 — A typical cutter is shown after use in a roughing operation.

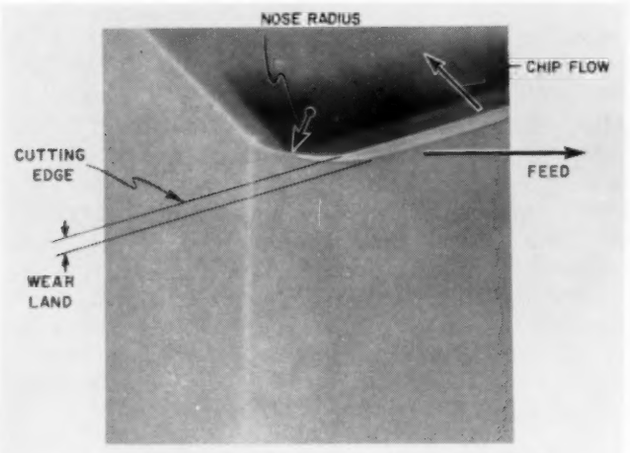
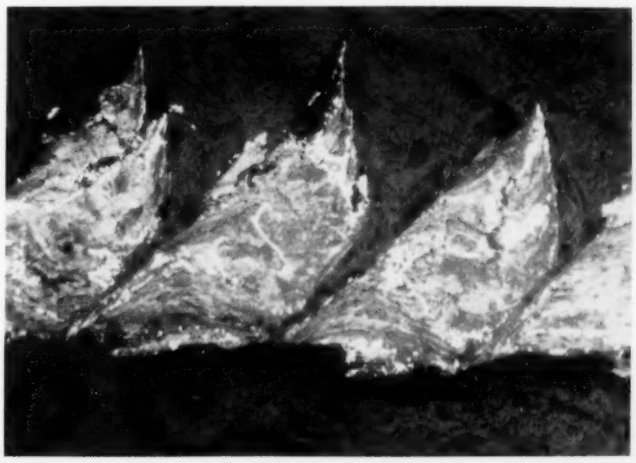


Figure 5 — An enlarged view of the cutter shows the edge wear.

away. Figure 5, an enlarged portion of the cutter shown in Figure 4, illustrates the typical "wear-land" which is approximately 0.012 in. for the cut shown in Figure 3. Thus far, no specific data has been compiled on wear-land and cutter life; consequently, the quantitative or qualitative functions thereof are not known. However, for the purpose of this article, the wear-land width was assumed to be directly proportional to the time in the cut if all other variables remain constant. Also, the safe and useful maximum life of a cutting edge has been assumed to be 0.020 in. of wear-land. In the future, as the data becomes more complete, it will be possible to confirm or rectify these assumptions.

The chips produced with ceramic cutters have been characteristically alike regardless of feed, depth of cut, shape of cutter, or variations in material from 50 to 70 Shore and 10 to 50 per cent of cementite. Figure 4 shows a typical chip, with a soft velvety texture on the top. On the bottom, adjacent to the cutter, it is quite smooth and shiny. When held in such a manner that light passes through the chip, it appears to have a lacy effect. The chips, even though they are ribbon-like, are actually a series of discontinuous segments loosely connected at occasional spots. This is shown in Figure 6, a transverse section through the chip in Figure 4, etched and enlarged 50 times. With respect to Figure 6, the work piece was on the left, and as the chip was formed it flowed toward the right. The surface of the chip at the bottom of the photo was in contact with the top face of the cutter as the chip flowed across it. Notice the plastic deformation in the crystalline structure along the bottom edge where it was compressed by the cutting action as it extruded out over the top of the cutter. Also notice the deformation along the sloping left side of each segment, the shear plane when the chip broke away from the work. The proportion of the height of the segments to their width seemed to be more or less constant with a ratio of approximately two to one, as shown in Figure 6. The pitch of the segments was to some degree indicative of cutter performance, and on all satisfactory heavy cuts a pitch of about 0.015 or 0.020 of an in. has been noted. This pitch appeared to be a function of the feed measured perpendicular to the cutting edge; this is, in effect, the thickness of the uncut chip, and is determined by the feed per revolution and the lead angle of the cutting edge. Specifically, this thickness is the feed times the cosine of the lead angle, consequently, the lighter the feed the finer the segmental pitch. By increasing the feed per revolution, and simultaneously reducing the cut speed to retain satisfactory cutter life, this pitch was increased until at approximately 0.050 or 0.060 of an in. the cutter was on the verge of failure regardless of cut speed, and could not be depended upon for consistent results. At this point the cut speed had been reduced to the point where ceramic cutters were no longer economical. The chip's appearance, as it was affected by the segmental pitch, became a very handy method of determining suitable feed rates. In addition, the sound produced by the cut seemed to be indicative of the nature of the chip. And, while the cut was in progress, this sound and the appearance of the chip became a relatively accurate indication for adjusting the feed to obtain suitable performance. It is assumed, of course, the cut speed and depth of cut remain constant. The sound thus produced by a satisfactory cut was somewhat like that made by quickly tearing a sheet of bond paper, a crisp sizzling noise. Then, as the segmental pitch was increased, the sizzling noise became a growl. It required very little ex-

Figure 6 — An etched chip, enlarged 50 times, illustrates the discontinuous structure.



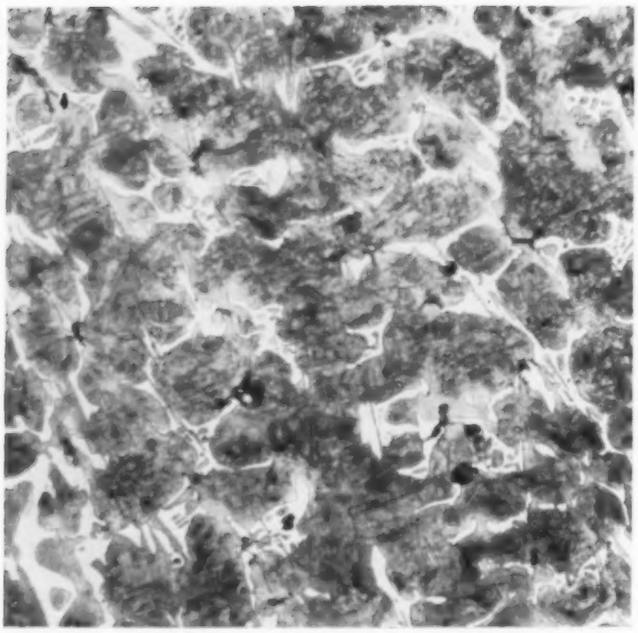


Figure 7 — A 100X photomicrograph shows the structure of the roll material.

perience to differentiate between a satisfactory sizzle and an unsatisfactory growl in order to adjust the feed to get the best cut.

Figure 7 is a photomicrograph, magnified 100 times, of the roll material cut in Figure 3. It shows the microstructure to be large grains of cementite, plus alloy carbides, scattered through a matrix of pearlite with an occasional flake of graphite. The cementite and related alloy carbides have been derived primarily from freezing of the eutectic (ledeburite) rather than from austenite. This microstructure is typical of all the material test cut so far with ceramic cutters. All the data presented here is from cutting similar material varying only in relative percentages of microconstituents and hardness thereof. The range of these microconstituents has been from 10 to 50 per cent cementite plus alloy carbides, and graphite from zero to two per cent with the balance pearlite. The average hardness of the test rolls varied from 50 to 70 Shore. Incidentally, average roll hardness is no criterion of machinability. The percentage of cementite has more effect on cut speed than any other single factor, with its form and distribution probably next most important.

For the specified range of materials, the best cut speeds for roughing cuts, using ceramic cutters, have been found to be from 120 to 210 fpm with feeds of 0.020 to 0.040 in. per revolution for depths of cut up to 1½ in. on the radius. On light finishing cuts the cut speeds can be increased appreciably, and for cut speeds of 60 to 100 fpm feeds have been increased to as high as 0.075 in. per revolution on deep cuts. However, no specific data have been compiled on such extra high or low speed cuts and these figures mentioned only show that ceramic cutters have a very broad range of performance. In general, ceramic cutters can be used under almost any condition of turning, with single-pointed tools, found suitable for carbide cutters. Then, starting from that condition, the cut speed may be increased rapidly while the feed is decreased slowly to a steady state where cutting time is reduced and horsepower at the cut is increased at a ratio of about three to one and occasionally as high as ten to one.

Furthermore, these ceramic cutters were found to be very durable, and they are neither temperamental nor sensitive to handling. They do not fail without warning as is generally supposed. They clearly show premature edge breakdown sufficiently ahead of complete failure to allow the cutter to be retracted from the cut while it can still be conveniently salvaged by regrinding. Manifestation of this warning, for the speed, feed and material ranges previously specified, is the occurrence of a small annular ridge around the freshly cut surface of the portion of the work which is being reduced to chips. If the cut is continued after the occurrence of this ridge, it will progressively become irregularly higher and wider, which is indicative of the cutting edge gradually flaking off. Then the entire cutter suddenly disintegrates. The time lapse of this progressive failure has varied from a few min to as much as ten min, and seemed to be somewhat related to the segmental pitch of the chip, that is, the longer the pitch the quicker the progression of failure. These ceramic cutters are generally treated about the same as carbide cutters except that the shanks must be made and maintained more accurately to better fit the ceramic insert, a point that is being stressed since mechanically clamped inserts for both ceramic and carbide cutting were used exclusively. Also, cutting edge geometry has proved to be about the same for both types of cutters. Specifically, for round tracing buttons of carbide, zero top rake with five to six degree clearance was used, whereas on ceramic cutters a narrow circular land of four or five degree negative top rake is added. For rectangular roughing inserts of either carbide or ceramics a five degree negative top rake (measured in a plane perpendicular to the cutting edge regardless of lead angle of that edge) is used with 5-degree clearance and a 90-degree cutting edge.

Some of the specific data compiled using ceramic cutters is presented herewith in the form of graphs. They represent preliminary data only, since the availability of suitable test rolls was rather limited. The high-powered cuts that have been described had an insatiable appetite for test rolls and the available test material was used up very quickly before any of the compiled data could be confirmed or the spread of the performance ascertained. The data is felt to be reasonably accurate, at least sufficiently so to establish definite trends of the characteristic performance of ceramic cutters as is illustrated on these graphs which follow.

Figure 8 is the effect of cut speed on tool life for a 1¼-in. diameter ceramic button, cutting 0.200 in. deep on the radius at 0.017-in. per revolution feed in material of 65 Shore containing 45 per cent cementite. The relationship of the variables shown follow the generally accepted equation $VT^n = K$, meaning cut speed times tool life to the nth power is a constant. This equation, if converted into logarithmic form, becomes log V plus n times log T equals K′; therefore, the relation of log V to log T is a straight line function, the slope of which is n. This relationship has been utilized to plot a curve with only two points of empirical data to establish n at 0.56 when the data is plotted to logarithmic scales as shown. The slope of this curve when compared to that for carbide, which is about 0.25, indicates that ceramics

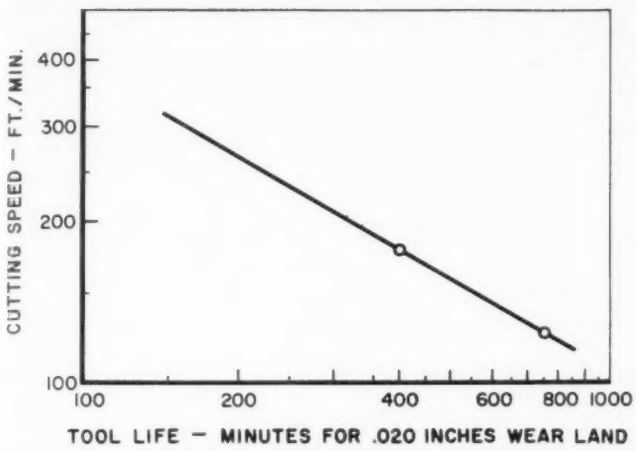


Figure 8 — The tool tested had a 1¼-in. diameter ceramic tip.

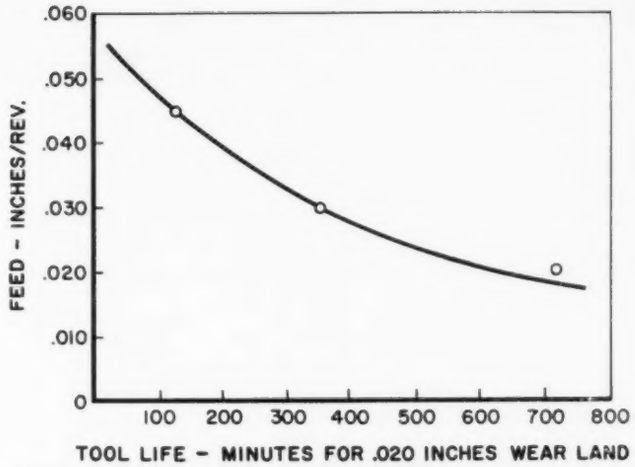


Figure 9 — The depth of cut was 0.200 in. on the radius at 125 fpm.

are about half as sensitive to changes in cut speed as is carbide.

Figure 9 is the effect of feed on tool life for a 1¼-in. diameter ceramic button, cutting 0.200 in. deep on the radius at 125-fpm cut speed in material of 65 Shore containing 45 per cent cementite. These conditions are the same as for Figure 8 except the cut speed is held constant and the feed varied. This curve shows that the life of a ceramic cutter is drastically affected by feed. The experience has shown that ceramic cutters are much more sensitive to changes in feed than are corresponding carbide cutters. It has been found that with carbide cutters it is better to adjust cut speed, while a cut is in progress, to obtain satisfactory results; whereas with ceramic cutters it is best to adjust feed, provided of course, that the cutting conditions are nearly correct as the cuts begin.

Figure 10 is the effect of feed on energy rate of metal removal for a rectangular ceramic cutter, which is set at a 45-degree lead angle and cutting ½ to 1 in. deep on the radius at 200-fpm cut speed in material of 58 Shore containing 15 per cent cementite. This curve indicates that more metal can be removed with the same horsepower as feed rates are increased. This relationship is of little importance, however, on machines that have adequate power to meet even the worst condition.

Figure 11 is the effect of cut speed on energy rate of metal removal for a rectangular cutter, which is set at 45-degree lead angle and cutting ½ in. deep on the radius in material of 55 Shore containing 13 per cent cementite. This curve indicates that more metal can be removed with the same horsepower as cut speeds are increased. For comparison, a carbide cut is also shown.

Figure 12 is the effect of cutter-nose radius on surface finish for light cuts in hard materials with sharp cutters. Cut speed has some effect on surface finish but it is slight and for most purposes can be discounted. However, cut speed has an appreciable effect on the appearance of the surface finish insofar as higher speeds produce a burnished surface which appears to be smoother than it really is. The difference between sharp carbide and ceramic cutters on total surface finish is also very slight and negligible. For the purpose of discussing the curves of Figure 12, the surface waviness is defined as the variation in surface finish produced by the scalloping effect of the cutter-nose radius as it is fed at a uniform rate across the work. The actual height of this waviness is the height of an arc of the cutter-nose

Figure 10 — A 45-degree lead angle at 200 fpm was used.

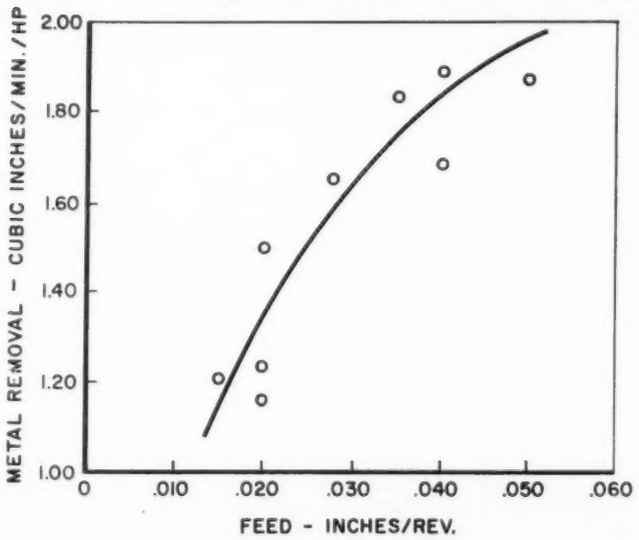
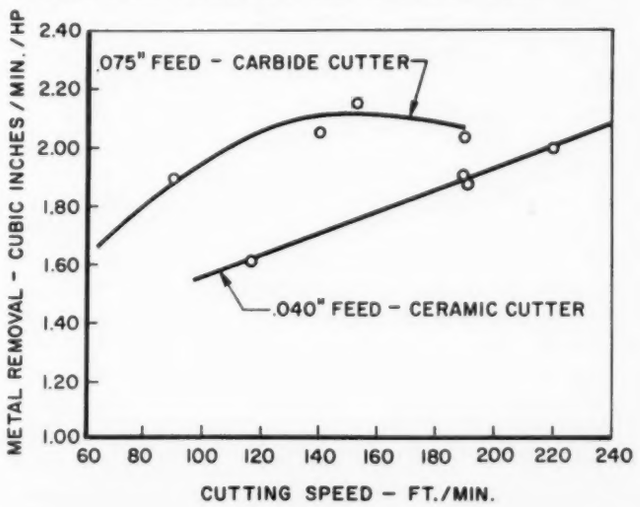


Figure 11 — The maximum metal removal rate for the carbide cutter occurred at approximately 140 fpm, the ceramic cutter approached this rate at 240 fpm.



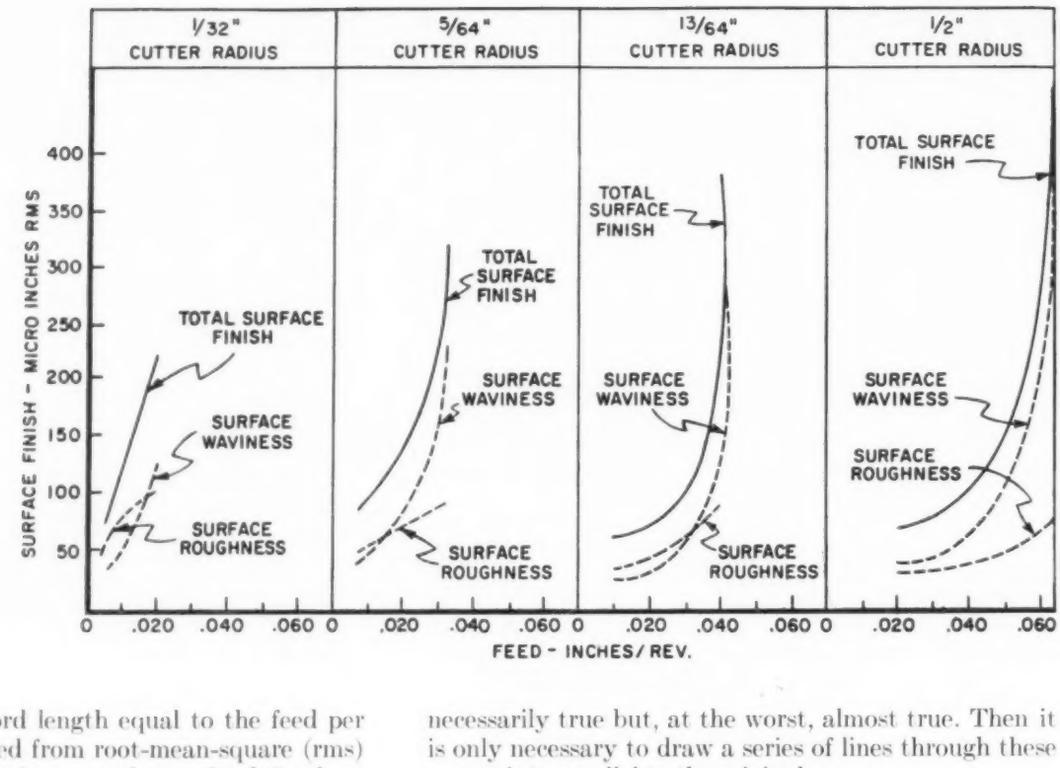


Figure 12 — The surface finish characteristics will vary with cutter radius and feed.

radius which has a chord length equal to the feed per revolution, but is plotted from root-mean-square (rms) measurements. The surface roughness is defined as modulations upon the waviness pattern caused by irregularities in the cutting edge and/or cutting action thereof. The total surface finish is the sum of these two parts. To put a relative meaning on the values of the surface finishes shown, we cite for example, a very good finish produced by a dead sharp carbide forming cutter on a piano rest is on the order of 40 to 50 micro-in. rms. For this type of cut the waviness is zero; therefore, the roughness is the total finish. The curves of Figure 12 show that on feeds below 0.010 in. per revolution the cutter radius is of little consequence but on feeds of 0.040 in. per revolution the radius is of considerable importance. Thus, for any given surface finish, the feed may be increased as the cutter radius is increased, thereby reducing the cutting time without affecting quality.

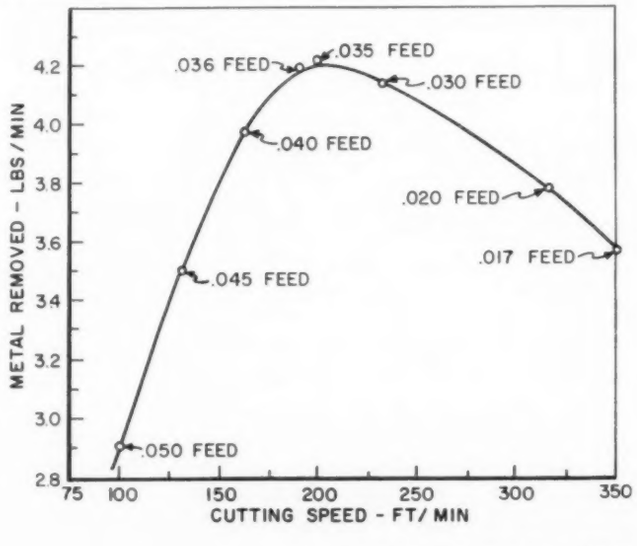
These curves and relationships just described are of technical and academic interest, and are of real value to a machine designer. But as such they have no practical value to a machine user. However, the information contained in these curves, when properly correlated, does become important to a user and it can make appreciable differences in his machining time when properly applied.

For example, take the data from Figure 9 and plot it on the graph of Figure 8, which can be done without error since both graphs are for the same cutter in the same material and the same depth of cut. This can be accomplished by selecting a group of points spaced at random along the feed-tool life curve of Figure 9, and then, since all these points are for 125 fpm cut speed, transfer them to the cutting speed-tool life graph of Figure 8. This produces the beginning of a family of curves, which when completed will show the effect of cut speed on tool life for various feed rates. To complete this family of curves an assumption must be made that the slope of the curve in Figure 8 is constant regardless of the feed rate, which is not necessarily true but, at the worst, almost true. Then it is only necessary to draw a series of lines through these new points parallel to the original curve.

This family of curves now shows the basic information of interest to a roll shop, but to conveniently use the information, another curve must be drawn up, such as the graph as shown in Figure 13. It is the combined effect of cut speed and feed on the time rate of metal removal for a 1¼-in. diameter ceramic button, cutting 0.200 in. deep in material of 65 Shore containing 45 per cent cementite, for a tool life of 120 min. Since cutting time is a function of the time rate of metal removal, this graph shows the best cut speed and feed to give minimum cutting time for a specific cutter life.

To produce the curve of Figure 13, it is first necessary to determine a desirable tool life based on the operating costs of the roll shop in question. Then, from the cutting speed-tool life family of curves previously described, obtain corresponding cut speeds for each of the feed

Figure 13 — Metal removal is indicated as a function of speed and feed using a 1¼-in. diameter ceramic insert.



rate lines for the predetermined tool life (which we have arbitrarily selected at 120 min for Figure 13). These cut speeds when multiplied by their respective feed rates are proportional to the time rate of metal removal for their respective feed-speed conditions. For those conditions and units shown in Figures 8, 9 and 13, cut speed multiplied by feed times depth of cut times three will give directly the rate of metal removal in lb per min, which, when plotted against corresponding cut speeds, yields the curve of Figure 13. The peak of this curve is the most economical place to operate for the conditions specified. By extrapolation of the curves in Figure 12 to 1¼-in. diameter cutter at 0.035 in. per revolution feed, a surface finish of approximately 80 micro-in. is obtained. For any other cutting conditions, new sets of curves will have to be developed. These curves can be made, as described, from very meager amounts of empirical data, obtained from a few short test cuts for the specific conditions desired.

This method of selecting the best cut speed and feed may be over simplified, but it is suggested as a convenient approximation to establish a starting point from which deviations can be determined by actual experience, the trend has been shown, each must select his optimum. Actually, there are many more parameters involved than those considered in this simplified version, and their interdependence is extremely complex. It is not yet fully analyzed nor understood, but in the quest for more specific data on the machinability of roll materials, a demand for more power and more rigidity always confronts us. This demand has been accentuated by the application of ceramic cutters and will continue to increase with improvements in cutter materials. This demand will be met by larger machines with capacities of 300 to 400 hp.

Discussion

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P. L. Haager: It was a pleasure working with the author while he was developing the design of his present roll lathe and his foresight in setting up the strict specifications for bearing rigidity and accuracies which have been built into these lathes is impressive.

It is obviously impossible to obtain chatterless cutting or high surface finishes at either high or low cutting velocities unless there is a structural balance between the rigidity factors of the shafts, housings and supporting bearings. This does not only include considerations of size of parts but also factors of their precision. This is true not only of the bearings used but also the degree of gearing accuracy required to maintain zero backlash and smooth power flow without torsional vibration. The report that there is no marking of the machined surface due to starts and stops under load and that the lathe is able to produce surface finishes down to 50 rms is conclusive evidence that the author has an excellent foundation, the super-lathe, upon which to test ceramic tooling.

It should be of interest to mention that the bore of the high precision spindle bearings are the same size as the mill roll that the lathe will turn. Precision-type bearings such as are normally used in machine tool spindles are also used throughout the drive.

Martin L. Weikert: In a large machine shop in 1912, all of the cutting tools in the shop were carbon tool steel. Later, the foreman carried a high-speed steel tool bit in his vest pocket which he loaned to anyone having tough metal to cut. When the job was completed, the tool bit was returned to his vest pocket. Gradually the cutting tools were changed over to high-speed steel.

In the early 1930's, tungsten carbide tools came into use for turning rolls. The development of these tools was slow until the contour lathe was used for turning rolls. Developments in carbide tools and contour roll turning lathes moved along at a faster pace.

There were times when the cutting tools could take more than the machine tool could give and machine tool designers developed lathes to get the full benefits out of tungsten carbide tools while the carbide tool makers improved their grades of carbides for turning rolls.

The indications are that ceramic tools will be developed for roll turning. In this development, will the cutting tools again be able to take more than the lathes can give?

Jack Binns: In the history of metal cutting machinery, there has always been a race between the machine and cutter, not for supremacy but to keep from being surpassed. A machine is designed and built to accommodate a particular cutter. Then the cutters are improved, necessitating an improvement in the machine. Then a new type of cutter is developed and the machine becomes obsolete. A whole new approach to the problem of machining is required, resulting in a completely different machine.

The development of ceramic cutters has now brought us to the threshold of just such a "whole new approach."

Norman Zlatin: Having spent 20 years in the investigation of the machinability of metals, it is of particular interest to note the application described in this article on the use of ceramic cutting tools on such a heavy turning operation. This is the first example we have seen in which ceramic cutters have been applied successfully on cuts as deep as 1 in. and at feeds up to 0.050 in. per revolution. It is a credit to the author that he has developed a machine which enables him

to machine hard rolls with ceramics using very heavy cuts. It must be surmised that the successful application of ceramics here is associated with the high rigidity of the lathe and setup. From Figure 4, it is apparent that the author used an exceptionally large ceramic insert as the cutting tool. Is such a large size of insert necessary?

It is also interesting to note that the ceramic tool was used successfully at cutting speeds ranging from 125 to 350 fpm rather than at extremely high speeds. The cutting speeds were, of course, limited by the exceptionally high hardness of the cast iron being machined.

Was the as-cast surface of the rolls also machined with ceramic tools? If so, how successful was the operation? Also, did chatter occur in contouring when the radius of the fillet to be cut was of equal diameter to the tool radius?

While the author should be commended for his attempt to optimize the selection of speeds and feeds, as indicated in Figure 13, it should be noted, as the author has, that more experimental data is required to substantiate the conclusion.

Jack Binns: Large inserts are preferred, they perform better than small inserts. Anything less than $\frac{3}{8}$ x $\frac{3}{4}$ x $1\frac{1}{4}$ in. is considered too small to be of value on high-powered cuts. A deep cut is more difficult to take with multiple small cutters than with one large insert.

The as-cast surfaces of rolls have been machined with ceramic cutters. Since an as-cast surface occurs only once on a roll, experience with as-cast cuts is very limited. An attempt is being made to accumulate more data. The example previously cited showed an improvement to 12 per cent of the carbide cutting time, and simultaneously gave a better cutter life.

There are no problems with chatter. If the work piece itself is sufficiently rigid, it is a simple operation to contour a radius in the work equal to the radius of the cutter. In fact, we recommend hogging a pass from solid just that way, feeding a $1\frac{1}{4}$-in. wide diameter button radially into the work, cutting a groove $1\frac{1}{4}$ in. wide to within $\frac{1}{8}$ in. of the finished contour, then stepping the cutter over $1\frac{1}{4}$ in. to a new position adjacent to the first groove and plunging in again, etc. Of course, if the work piece is long and slender, lacking sufficient rigidity itself, then it will be necessary to support the roll in housing instead of centers to perform such a cut.

Arthur R. Kommel: In the author's discussion he mentioned that the thinnest cutter used was $\frac{3}{8}$ in. thick. It is assumed that by thickness the author means the vertical dimension of the cutter insert when the tool is positioned in the lathe for turning. What is the effect of insert thickness upon efficiency and tool life?

Jack Binns: At present, data on quantitative effect of insert thickness on efficiency and tool life are rather nebulus. There is no data as yet on the degree of effect, only whether satisfactory or not. We have not had satisfactory results in high-powered cuts with inserts smaller than $\frac{3}{8}$ x $\frac{3}{4}$ in., with performance improving as the thickness increased. If cutters are limited to $\frac{3}{8}$ x $\frac{3}{4}$ in. performance will be best if the insert is set with the $\frac{3}{4}$-in. dimension in the vertical position.

Glenn R. Webster and Donald P. Hunt: In the past, ceramics have been associated with high speeds and light depths of cut. This article will do much to refute this strict classification and extend ceramics also into slow speed and high metal removal rates.

Over the past three years, ceramics have been successfully applied to finish turning and semi-finish turning of mill rolls. The strength retention property of these cutters with elevated temperatures and their high abrasion resistance allowed faster machining and consequent economies over carbides. In certain cases, it was possible to rough turn as-cast mill rolls.

In all cutting applications so far, the most important factor governing tool performance has been rigidity. With the advent of the super-lathe, a machine was available upon which the ceramic cutters could be evaluated with no concern for rigidity. The cutting parameters described in the article are typical of those employed in the tests.

The author has brought out a very important point in his discussion of the handling of ceramics. Ceramic cutting tools need not be handled like china but they do require more care than carbide. For example, correct seating of the tool in the toolholder is of great importance. Useful tool life of a ceramic is readily determined by observing the appearance of the cut surface which is about to be reduced to chips. At speeds in the range of those discussed, a tool need never be broken and can be withdrawn and reground after the proper wear-land has developed. The charts on surface finish are very interesting and their development will prove beneficial in mill roll turning. There have been cases where managers would not believe a finished surface was turned with a ceramic, but thought it ground.

The major cause for past failure of ceramic cutting tools has been adverse machine conditions. These have been tolerated since it has been possible to compensate for them with more conventional tool materials.

The ceramic tool industry is striving to improve its product in order that increased metal removal rates may be realized and with this type of machine they may be even more attractive to industry. ▲

There is a constant demand for copies of "The Modern Strip Mill" published by the Association of Iron and Steel Engineers. If your copy is not in use please get in touch with us.

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Bar and Strip Mill Loopers

by W. E. KOLLEK, Assistant Vice President—Engineering,
Foundry and Mill Machinery Group, Blaw-Knox Co., Pittsburgh, Pa.

. . . . looper regulation of inter-stand tension reduces undesirable strip or bar cross-section reductions caused by excess tension. Moreover, integration of the looper control system with a gage control system can produce a final product with better gage tolerance . . . .

THE users of rolled steel products are constantly demanding better quality and closer finished tolerances of rolled steel products. This is true not only for flat rolled products such as plate, sheet and strip but also for structural sections such as rods and bars.

As a result, the firms producing rolled steel products as well as the mechanical and electrical equipment suppliers are constantly requested to improve operating procedure and design new equipment to meet these demands. Much effort has been expended during the last several years to automatically control the finish dimensions of the rolled steel product. Progress is especially noteworthy in the continuous mill field.

The high-speed continuous mill of today, producing quality products to accurate dimensions, is a contrast to the early continuous mill. Continuous mills initially were so arranged that several mill stands were driven by one motor through a gear drive. Speeds were slow and it was necessary to carefully select roll diameters and pass reductions to suit the established mill stand speeds so that the product being rolled would not be subjected to excessive or insufficient tension. Of necessity, it was common practice to roll the product with tension between adjacent mill stands.

Tension during rolling on some products is not considered objectionable as long as the cross-sectional area being rolled is large, as is the case when rolling in the roughing stands; however, when rolling in the finishing stands, where the cross-sectional area is small, excessive tension is very detrimental to the rolling of accurate finished products.

In connection with continuous bar mills, the more recently installed bar mills are equipped with motor drives for each finishing stand and also, in many cases, for each of the intermediate stands. This arrangement simplifies matching of mill speeds, yet it still requires considerable skill on the part of the operator to regulate the speeds to meet the variable conditions during rolling.

In order to assist in regulating the mill speed, loopers were provided between adjacent stands. The objective of the looper is to store an adequate amount of material, between the stands, which can be taken up as speed

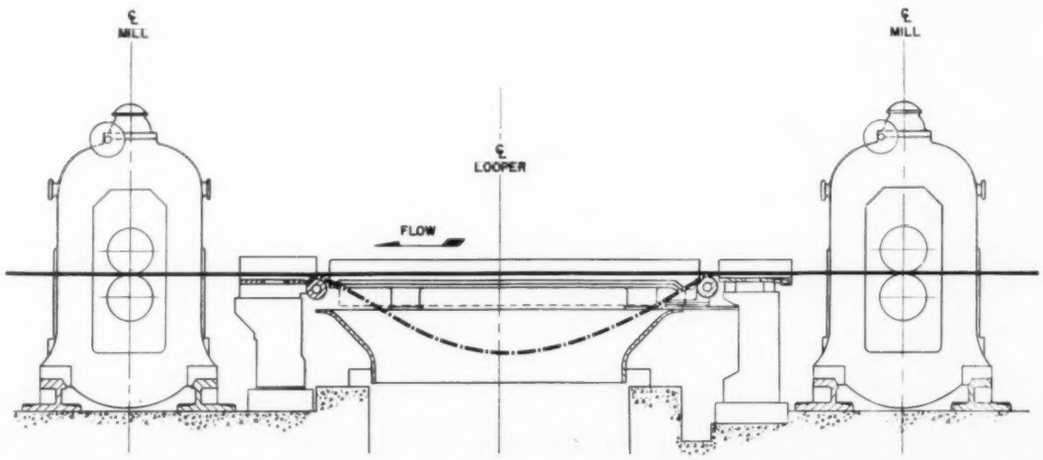


Figure 1 — The drop looper allows the bar to assume a catenary loop.

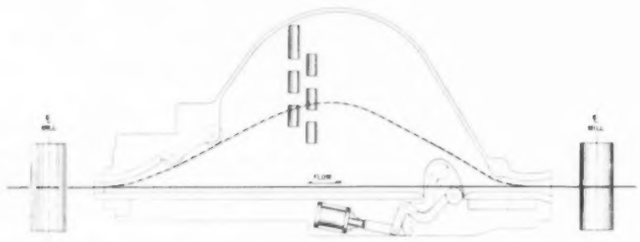


Figure 2 — In side looping the bar is supported on a looping floor.

changes occur, without creating excessive tension in the bar.

Various designs of bar loopers were employed and many are still in use. Some mills, because of the section being rolled, employ drop loopers, others use side loopers. With these designs of loopers it is possible, by observation, to control the loop size through mill motor speed adjustments.

Drop loopers generally consist of a guide trough having a hinged bottom which can be opened quickly. Figure 1 shows a drop looper. Its function is to guide the bar from one mill stand to the next. When the bar has entered the succeeding stand, the bottom of the trough is opened, and the bar drops and forms a vertical hanging loop. The drop looper design does not employ a looper roll.

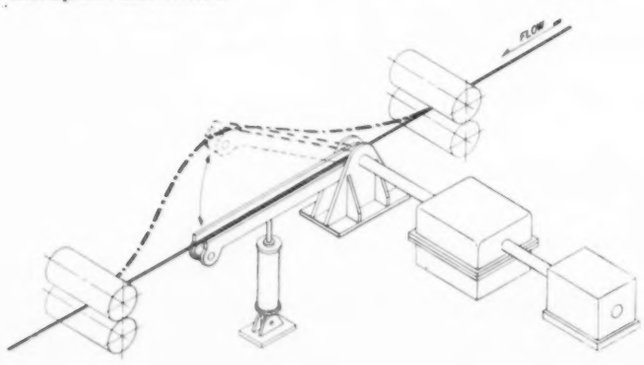
Side loopers as shown in Figure 2 are more versatile inasmuch as the loop is supported on a looping floor. The bar is first directed through a trough to the succeeding mill stand and then the loop is formed by means of a looper roller which moves horizontally to direct the bar sideways onto the looping floor.

Both the drop looper and the side looper were initially manually operated, but later dependable electrical devices were employed providing automatic operation.

Some European bar mills have, for some time, used vertical uploopers. These loopers, mostly of the lever-type design (Figure 3) form a loop and support the bar during tension-free rolling. The movement of the looper arm is transmitted to the motor control of the following mill stand to adjust the mill speed so that the loop remains constant. Only recently have uploopers been employed on continuous bar mills in this country.

It can be stated that the looper is a major factor in the success of modern, continuous, individual-motor-driven, bar mills. Since tolerances of the finished product depend largely on the accurate operation of the up-

Figure 3 — Uploopers have been in use for some time on European bar mills.



looper, modern continuous mill loopers must meet many rigid, yet selective, requirements. These are:

1. Maintain a controlled loop length between adjacent mill stands.
2. Support the loop and yet produce a tension-free bar.
3. Maintain the loop under a uniform controlled tension.
4. Move rapidly above or below the pass line as operation requires.

For a new bar mill, furnished to a major steel company in the Chicago district, hydraulic loopers were developed which embody these features. Figure 4 shows the arrangment of equipment between adjacent mill stands. This equipment includes mill guides which are so constructed that they can be swung out quickly to clear the housing window to facilitate roll changings; guide troughs which are so constructed that they can be easily rolled out of the mill line; and the looper assembly. The looper control permits loop size adjustment to be made from the operator's pulpit through a range 6 to 18 in. above the pass line. Preset loop height is maintained through the signalling of the looper roll position to the mill motor speed regulator, which adjusts motor speeds accordingly.

If the loop increases in length and the roller moves up correspondingly, a signal, obtained from the roller position, is transmitted to the motor speed regulator to adjust the roll stand motor speed. If the loop decreases, the roller moves down and the opposite corrective signal is obtained. The action of the looper roll follows a sudden loop growth or loop shrinkage instantly, thus assuring accurate speed control.

In order to track the bar through the mill, a slight tension force must be applied. This tension is controlled by a variable-rate pneumatic spring located below the looper roller. The pressure in this pneumatic spring is adjustable so that the correct tension can be established. A wide range of selected tension can be accurately maintained to meet the requirements of the product range being rolled.

Figure 5 shows the arrangement of the looper stand. The looper roll is mounted on the crosshead of a hydraulic cylinder which moves the looper roll vertically. Between the looper roll and the crosshead are mounted a hydraulic positional servo-valve and the penumatic spring. The crosshead is guided in the base frame by two heavy guide columns. The hydraulic cylinder mentioned is also mounted on this base frame. For dependable lubrication of the looper roll and the guide column bearings, a high-pressure, positive metered oil circulating system is provided. This system supplies oil under pressure to each looper stand. The oil flow is divided into three parts, two parts going to the guide column bearings and the third part to the looper roll.

Hydraulic pressure is applied to both the upper and the lower sides of the cylinder which activates the looper roll assembly. The pressure on the lower side is modulated by the hydraulic positional servo-valve. By increasing or decreasing the pressure in the lower side of the cylinder, the servo-valve causes the piston assembly with looper roll and pneumatic spring to be raised or lowered. As loop size changes occur, the looper roll, under the influence of the pneumatic spring, moves upward with

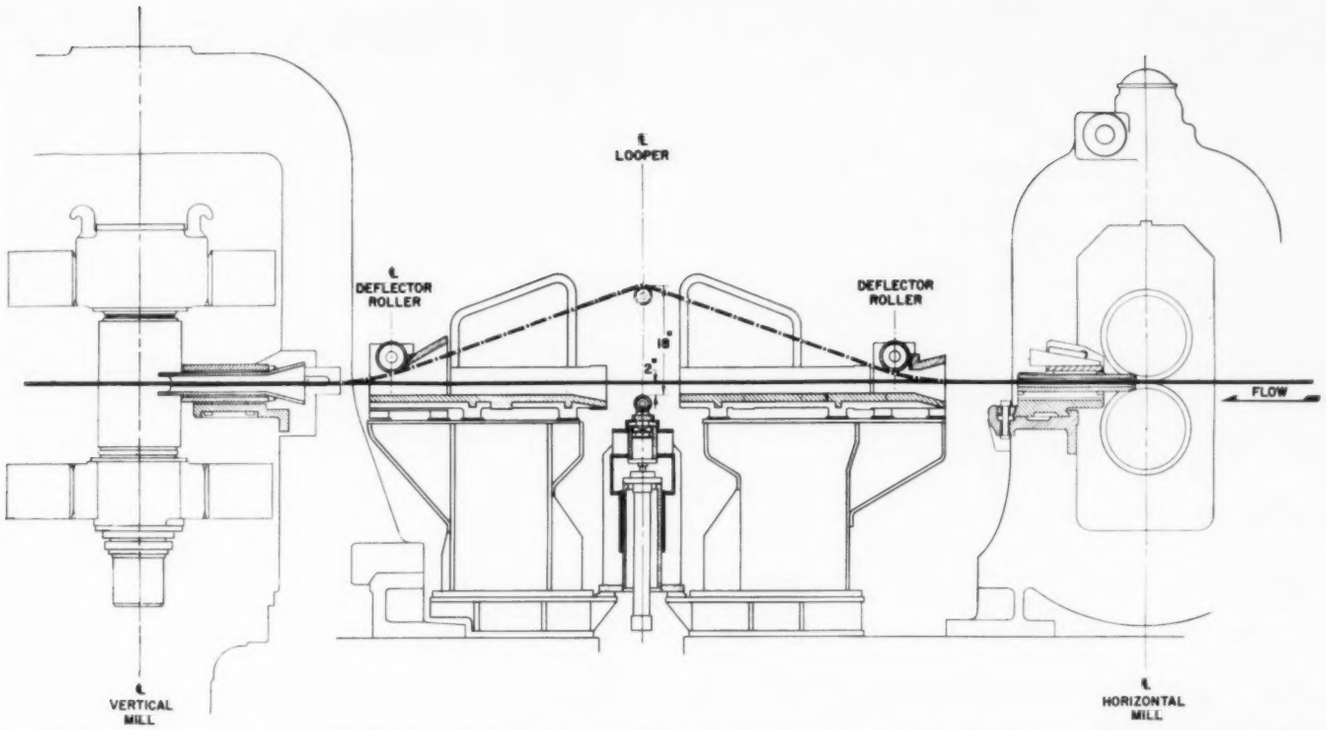


Figure 4 — The hydraulic uploopers are equipped with position indicators which signal the motor speed regulator to adjust loop height.

the loop. In so doing, the servo-valve is actuated causing a cylinder pressure change; this pressure change then causes the piston rod and looper roll movement. The direction of the movement of the roll is the same as that of the loop, and under steady-state loop size conditions, the looper maintains a null state. An override valve, actuated from the programmer, is incorporated in the looper system to raise and lower the looper rapidly when the bar is entering or leaving the mill stand. This valve also rapidly lowers the looper in case of emergencies. Mechanical feedback from the looper is introduced into the motor speed regulator for motor speed control.

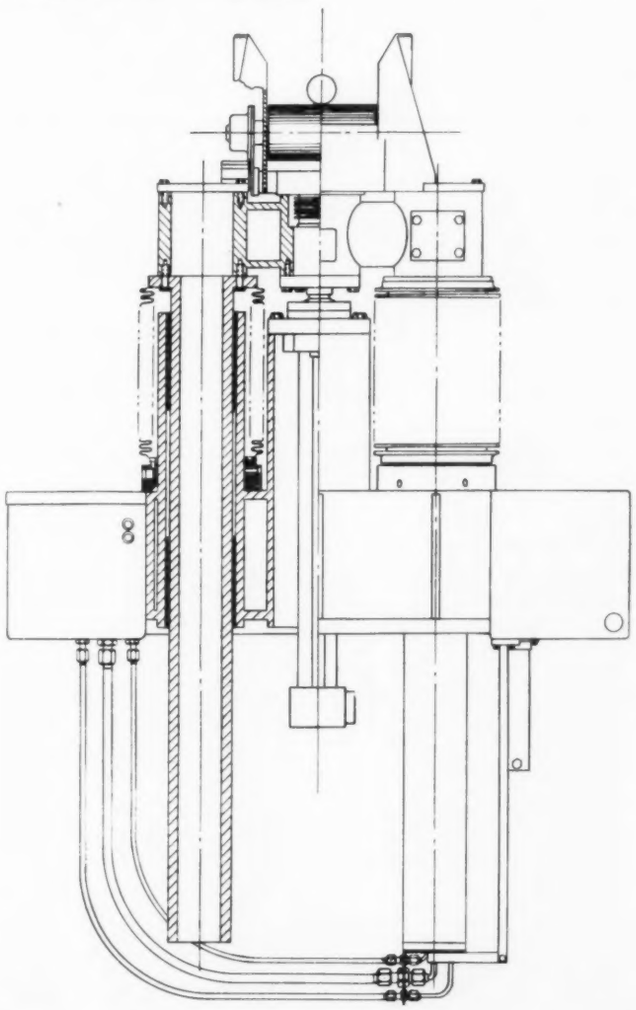
Hydraulic power to the loopers is provided from a central pumping source. Figure 6 shows the components of this power unit. In order to achieve maximum reliability, performance and service life, the latest techniques in hydraulic systems have been employed. These include:

1. A pressurized reservoir and low-pressure system.
2. The use of corrosion resistant materials throughout the fluid system.
3. High-lubricity, nonflammable hydraulic fluid, micronic-type filters and axial-piston, variable-volume, compensating-type pumps are used.

A dual-pump-motor system with automatically operated selector valves is incorporated to give standby insurance. Should one pump fail to maintain system pressure, the other pump will automatically cut-in, so that the system pressure is continuously maintained. Duplicate filters are provided in the pump circuits to allow pump, filter or motor servicing without system shutdown.

Figure 7 shows the hydraulic power unit assembly with the reservoir and pumps which are direct connected to the motors and filters. An air compressor complete

Figure 5 — Positive lubrication is assured for the roll and the guide column bushings.



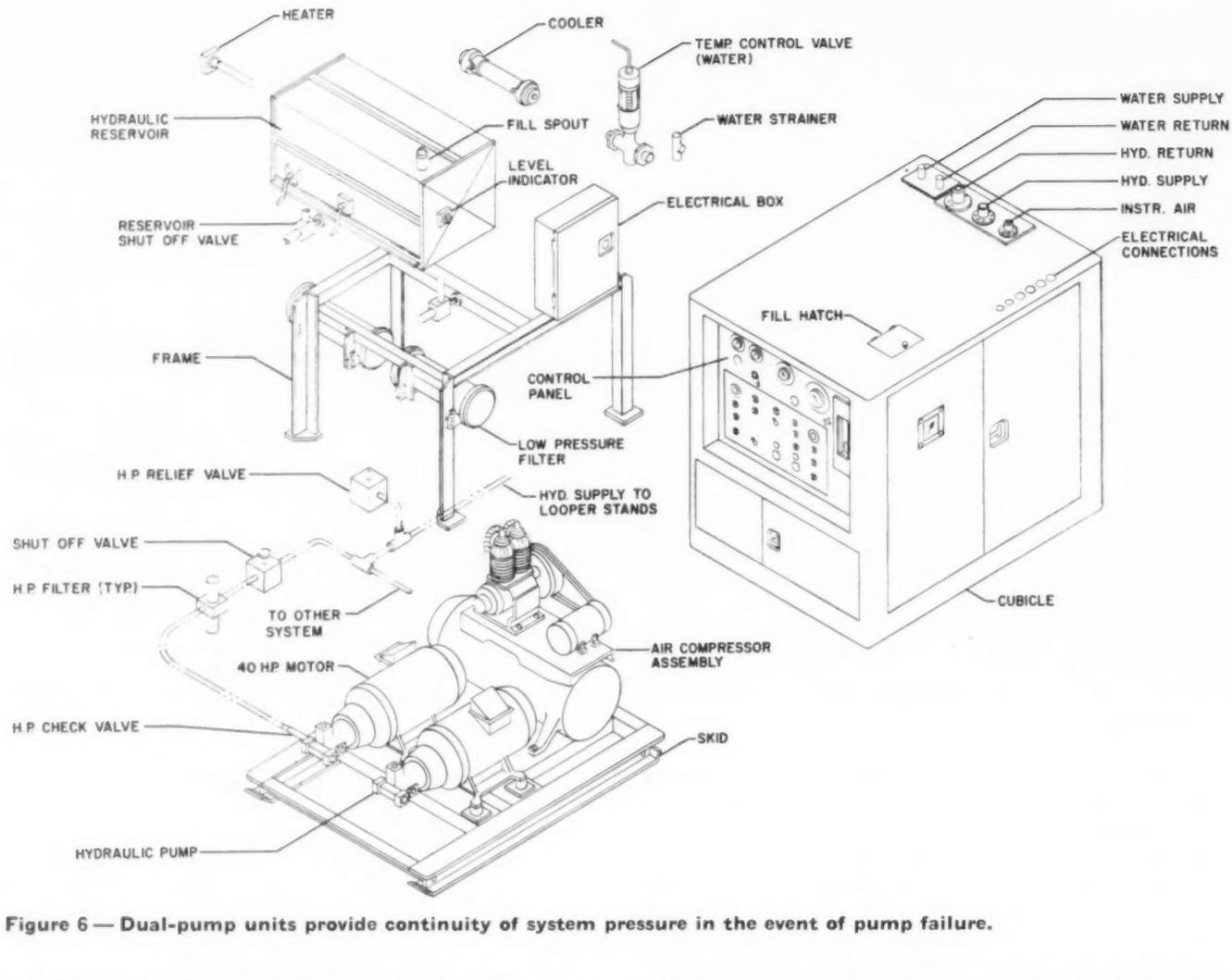


Figure 6 — Dual-pump units provide continuity of system pressure in the event of pump failure.

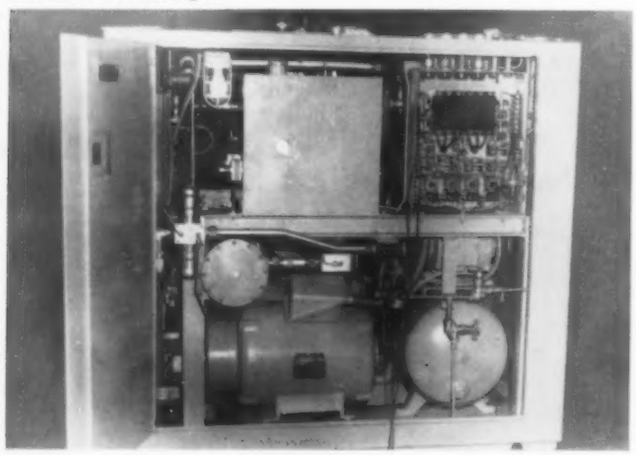
with motor, filters and dryer is provided to pressurize the low-pressure system and air controls. All of these components are mounted in cabinet with doors on both sides for easy access to the equipment. Figure 8 shows the cabinet with the control panel.

On the new 16-stand bar mill previously mentioned, the loopers are installed between the roll stands of the finishing train. Five loopers are employed. Figure 9 shows a schematic of the control devices and components required for automatic operation. In order to initiate operation of the looper control, a photo-cell is located at the delivery side of stand 9 to sense the bar entering stand 10. The signal from this photo-cell starts preset counters (designated as front-end counters) which count at a rate in step with the tachometer generator connected to stand 11 mill motor.

As soon as the counters have reached the preset count, they will energize the override valves, which operated the hydraulic cylinders to raise the loopers. The counters will also initiate electronic time delay relays, which in turn will connect the looper position potentiometers to the appropriate mill motor speed regulators.

Looper position provides the reference to the mill motor speed regulator, of the stand immediately following the looper, by a looper position potentiometer. When the looper roll moves from a selected position, the looper position potentiometer signals the appropriate mill motor speed regulator and also signals this change to all the following mill motor speed regulators. This arrangement minimizes loop height variation between succeeding stands (caterpillaring). When the photo-cell at the delivery side of stand 9 no longer detects a bar, a second set of counters (designated as tail-end counters) will start counting. When these counters have reached their preset count, they will de-energize the respective override valves, causing the hydraulic cylinders to drop the looper roller immediately.

Figure 7 — Hydraulic power is supplied by a compact, unitized assembly.



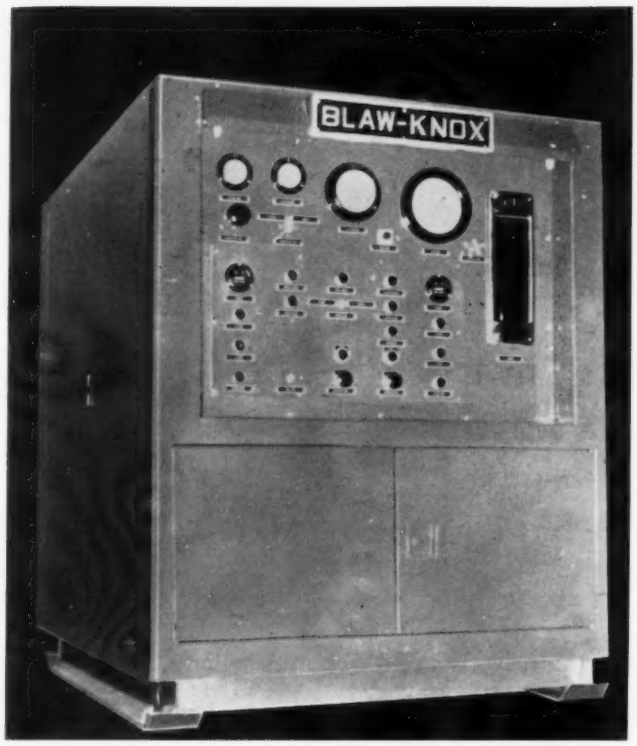


Figure 8 — All hydraulic system controls are mounted on the front panel of the unit.

The foregoing is a description of a hydraulic bar mill uplooper which constitutes a major factor in the production of quality bars rolled to close tolerances as required by the steel industry.

The consumer requirements for flat rolled products, especially strip, are just as stringent as those for bar products. With the increasing demand for uniformity of finished strip from the cold mill, it became apparent that in order to produce better quality cold rolled strip, the quality of the continuous hot rolled strip must be improved. Production of hot rolled strip of uniform thickness and width presents many problems due to the many variables encountered in rolling, such as strip temperature, roll opening, metallurgical requirements and tension. Automatic gage control is a major means toward better hot rolled strip.

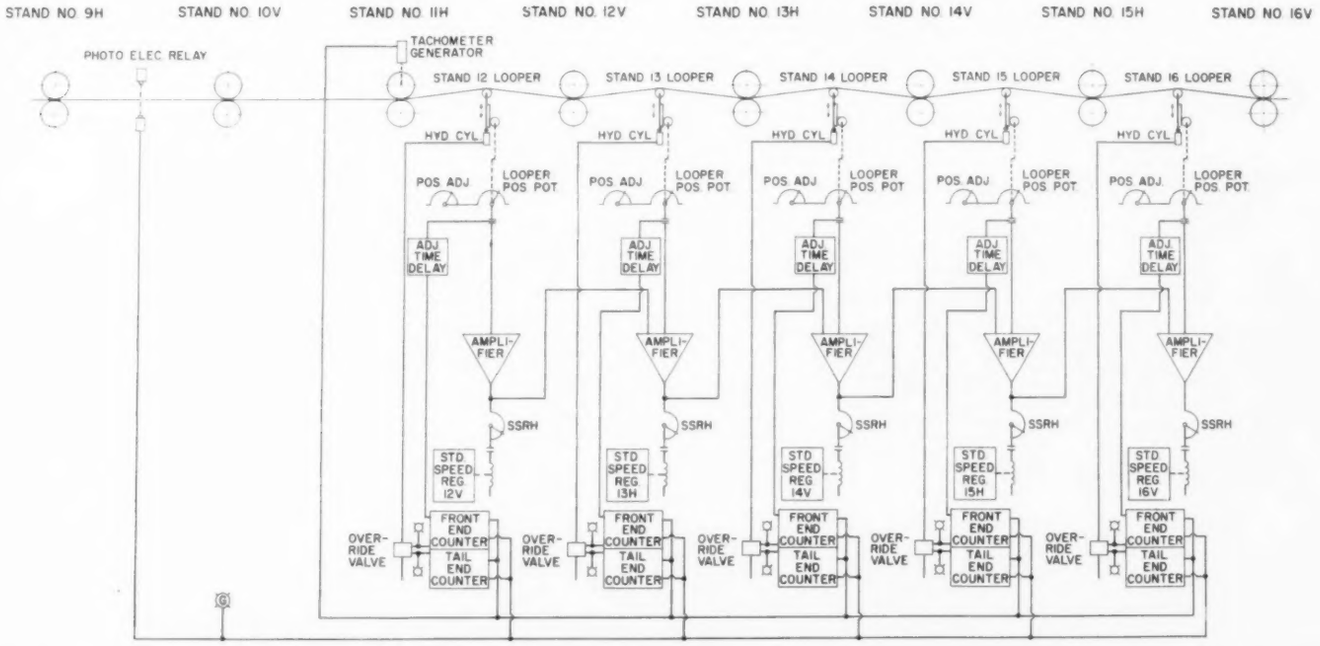
With the application of automatic gage control, it becomes desirable that strip tension be closely regulated and that the strip be rolled with controlled loops between stands. This is in contrast to the earlier strip mills which were operated with free loops. Such free loops were necessary because the motors and controls then available were slow responding, and the speeds of the stands were adjusted manually. Loopers were provided between the stands and such loopers consisted of a looper roll mounted on lever arms which raised and lowered the looper roll. The lever arms were motivated by either cylinders or, as in most cases, by a constant-torque motor through a gear drive. These loopers did not raise or lower fast enough to follow the strip, nor did they maintain constant tension.

When operating with these loopers, the mill speed is set so that a loop will form between stands. The stand speeds are then adjusted so that the loop is eliminated and the strip is running level between the stands with the looper roll below pass line. By this so-called "speed operation" method, good strip can be produced, but this method also invites application of excessive tension which affects changes in the thickness of the strip at the front and tail ends where the material is rolled without tension.

Since some tension is necessary to properly track the strip through the mill, the object is to provide and maintain sufficient tension between stands for proper tracking without creating excessive tension, which causes gage and width variations in the strip.

Extensive experimental work has been conducted covering automatic gage control on hot strip mills. The experiments showed that strip thickness variations are due to temperature variations in the material and tension variations applied to the strip. It was also determined that proper tension can be used as a means to

Figure 9 — The movement of one looper roll causes a change in speed of all the following mill stands.



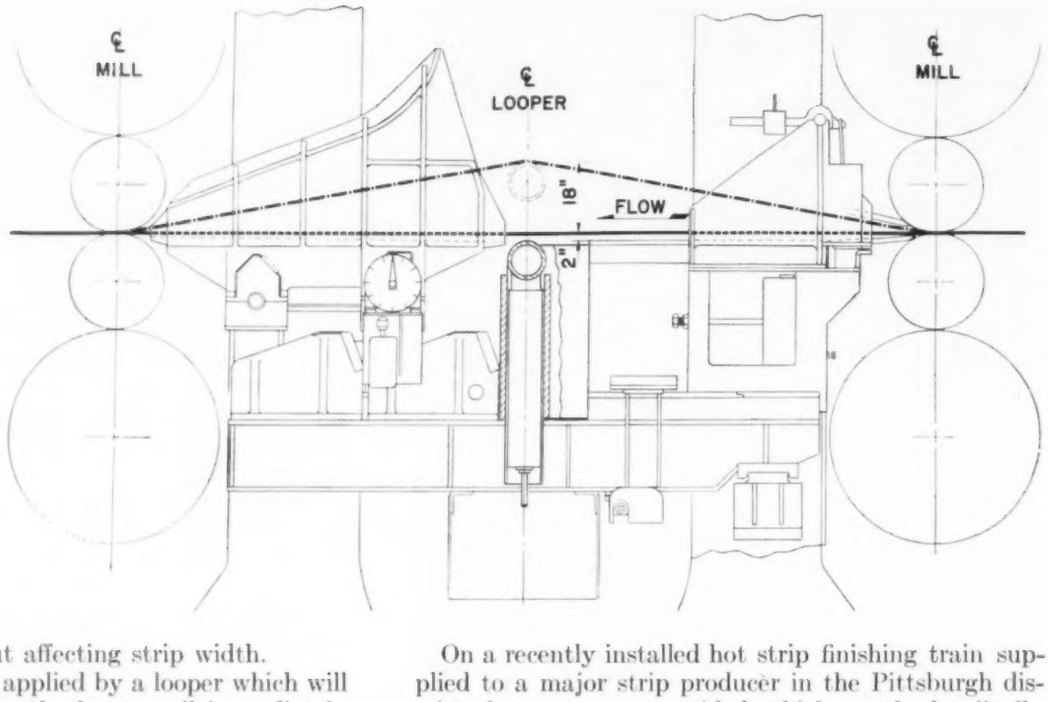


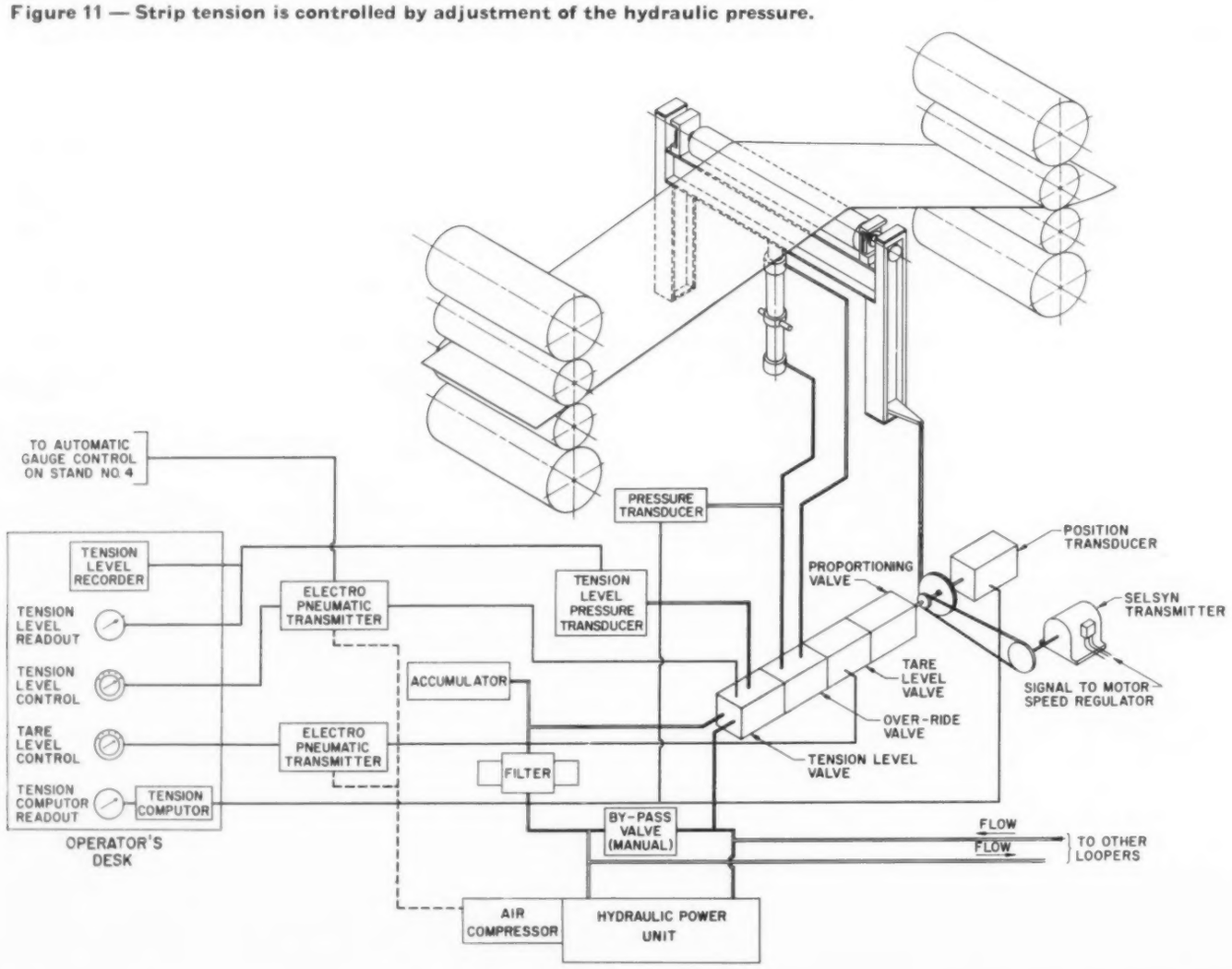
Figure 10 — The looper illustrated is designed to operate at a mean height of 12 in. above the pass line and to maintain constant strip tension. Looper height shown is maximum.

control thickness without affecting strip width.

Proper tension can be applied by a looper which will respond rapidly and raise the looper roll immediately after the front end of the strip has entered the succeeding stand, and will lower the looper as soon as the tail end is about to leave the preceding stand.

On a recently installed hot strip finishing train supplied to a major strip producer in the Pittsburgh district, loopers were provided which are hydraulically actuated. They operate at a mean loop height of 12 in. within a controlled range of 6 to 18 in. above the pass line and will maintain constant strip tension regardless

Figure 11 — Strip tension is controlled by adjustment of the hydraulic pressure.



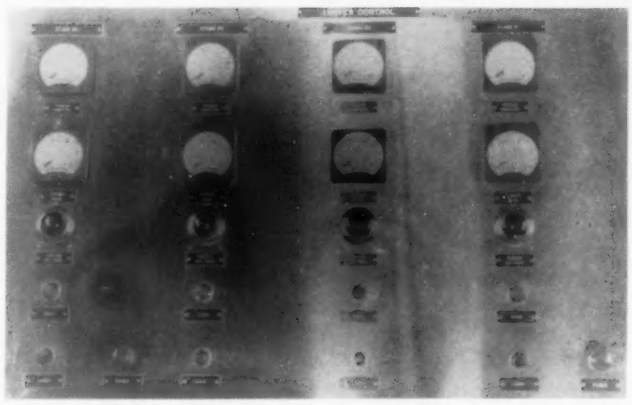


Figure 12 — Control and read-out devices are located on a control desk in the mill pulpit.

of loop size changes. Constant tension is maintained from 2 to 18 in. above pass line or higher if desired. The speed regulating range can also be changed as desired. The looper system is arranged to be used in the gage control system. The size of each loop is measured by the position of the looper roll, which in turn transmits a signal to the appropriate mill drive motor calling for a change in speed as required to maintain the loop size. Each looper controls the speed of one roll stand, and any change occurring is corrected by its particular looper. However, any change in one loop is reflected in "chain reaction" fashion to the other loopers, thereby maintaining over-all mill speed control. Figure 10 shows the equipment between two adjacent mill stands with delivery guides, entry guides and the hydraulic strip looper which consists of a horizontal looper roll mounted on top of the piston rod of a vertically-mounted hydraulic cylinder.

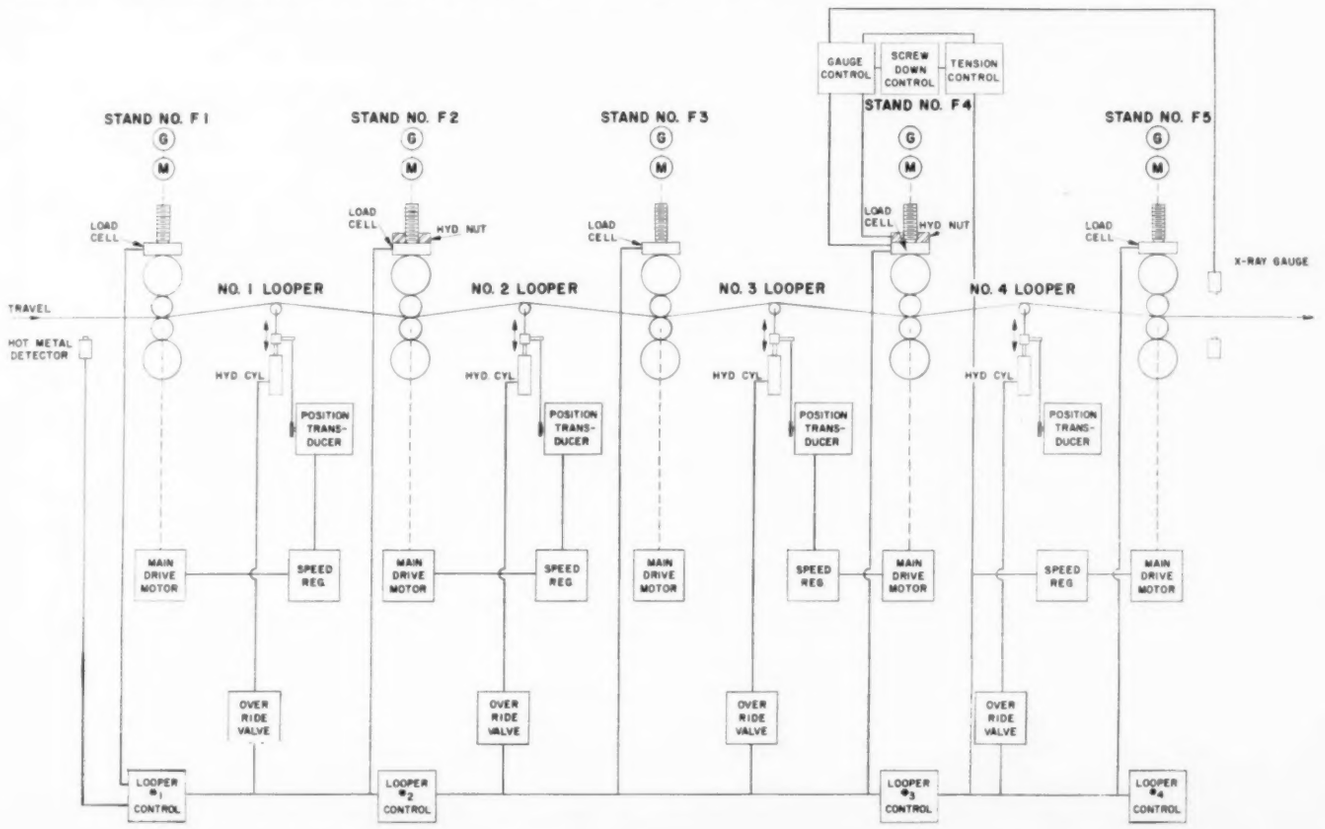
A schematic diagram of the looper control circuit is shown in Figure 11. Hydraulic pressure is applied to the lower side of the piston causing it to move upward, forcing the looper roll against the moving strip and forming a loop. Constant strip tension is maintained despite loop height changes by modulating the hydraulic pressure. Modulation of the hydraulic pressure is accomplished by a regulating system employing mechanical feedback from the piston position, which is also looper roll position. The modulation level or strip tension is adjustable remotely and can be selected for each looper by setting a calibrated dial in the pulpit. Each position of the dial corresponds to a total strip tension. Adjustment is stepless over the tension range. An override control is provided to raise or lower each looper immediately as the strip enters or leaves the mill stand. The override control also permits raising and lowering of one or all loopers by means of push buttons.

Tension level read outs register the actual total strip tension for each looper. This tension is also recorded on the tension level recorder for future reference or correlation with product control data.

The actual modulated looper force is measured by a pressure transducer. This measurement is transmitted to the tension computer, which also receives a measurement of looper height from the looper roll position transducer. With these two measurements the computer determines the actual total strip tension for any looper height, which is then reflected on the tension computer read out.

Electropneumatic transmitters serve to convey the pulpit control settings to the respective devices. On the control desk shown in Figure 12 is located the tension level control dials, tension read out, computer read out,

Figure 13 — Tension signals are used, in the gage control system, to initiate screw-down movements on stand F4.



manual raise and lower buttons, panic buttons and the selector switch for selection of either manual or automatic operation. The automatic control scheme is shown in Figure 13.

When the strip enters the stand F1 mill rolls, the load cell provides a signal to energize a timer, whose timing function is inversely proportional to the mill speed. The timer provides the signal to the override valve to raise looper roll 1.

In the same manner looper rolls 2, 3, and 4 are raised as signals are received from the respective load cells.

The looper roll, through the selsyn position transmitter, provides a signal to the speed regulator of the appropriate mill motor to change the mill speed so that the looper roll will be positioned 12 in. above pass line.

It should be noted that the speed of stand F3 is not regulated by a looper. Therefore, loopers 1 and 2 regulate the speeds of stands F1 and F2 respectively, while loopers 3 and 4 regulate the speeds of stands F4 and F5.

Automatic control of the total tension of looper 4 is provided to assist in automatic gage control. The signal received from the X-ray gage can be used to correct the screw setting or to automatically change the strip tension. This automatic tension change utilizes the originally selected strip tension as the base from which it adds or subtracts to increase or decrease tension.

When the hot metal detector located ahead of stand F1 no longer detects hot strip, it will provide a signal which, through a timer, de-energizes the override valve and lowers looper 1. When the load cell on stand F1 indicates that there is no strip between the rolls, a signal is provided which will, again through a timer, de-energize the override valve and lower looper roll 2. In the way loopers 3 and 4 are lowered by signals from the load cells of stands F2 and F3 respectively. When any emergency button is actuated, all the loopers will lower immediately. The hydraulic power source needed to actuate the above strip looper is similar to the one described for the bar mill looper.

SUMMARY

An advanced hydraulic looper design as applied to bar mills and to hot strip mills has been discussed.

The bar mill looper is extremely sensitive and responds most rapidly to changes in loop height between stands. Preliminary reports of operation indicate that the loopers are meeting all expectations and that results are setting new standards of performance. Tolerances of product thickness of head end to tail end of bars are less than one tenth of commercial tolerances.

The hydraulic hot strip mill looper will maintain a constant tension which is readily adjustable by the operator and can be easily repeated for corresponding schedules at a future date. When operating in conjunction with an X-ray gage, the looper will assist the automatic gage control. Preliminary results of operation are meeting all expectations. ▲

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Evaluation of Checker Design

by F. D. NELSON, Assistant to Manager, Steel Production,
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. . . . the use of double-pass checkers of sufficient volume permits higher combustion air preheat with a subsequent flame temperature increase and a fuel consumption decrease. Also, with proper furnace operation, tons per hr can be increased compared to single-pass checker operation . . . .

WHEN No. 3 open hearth shop was built, two furnaces were designed with single-pass checker chambers and two furnaces with double-pass chambers. The purpose of this design program was to evaluate the two types of regenerators in terms of production, fuel consumption and maintenance costs. Both style chambers were so designed that in the event one system was found to be more efficient, conversion would be possible without any change in existing steelwork or checker binding.

ORIGINAL CHECKER CHAMBERS

Single-Pass Design

Inside length, ft-in.	29-11½
Inside width, ft-in.	25½
Checker volume, cu ft	12,251
Total checker depth, ft in.	15-9
Type flue	Open basket weave
Flue size, in	6 x 10½
Distance from top of checkers to roof, ft-in	4-2

In the single-pass design, the gases pass from the furnace down the down-take traveling a fairly direct path over the bridge wall through the checker, impeded only by the checker brick themselves which are the heat exchangers. The waste gas gives up a large portion of its heat to the checker brick and when the furnace is reversed, the incoming air moving through the hot checkers is preheated and used in supporting combustion of the fuel. However, with this design and the size of the checkers as stated, certain portions of the checker work do not have sufficient contact with the gas flow to do an efficient job of preheating the incoming air. The depth dimension shown is limited due to the water level of the area.

Double-Pass Design

Inside length hot pass, ft-in.	14-3
Inside width hot pass, ft-in.	25-½
Inside length blind pass, ft-in.	2-9
Inside width blind pass, ft-in.	25-½
Inside length cold pass, ft-in.	10-8½
Inside width cold pass, ft-in.	25-½
Checker volume, cu ft	10,470
Total checker depth, ft-in.	16½
Type flue	Open basket weave
Flue size, in	6 x 10½
Distance from top of checkers to roof, ft-in.	3-9½

In the double-pass design, two dividing walls are utilized to force the outgoing gases and incoming air to pass over practically all of the checker brick. The effect of this design increases the heat interchange yielding higher preheat air temperatures and therefore, a hotter flame in the hearth.

DESIGN AND PRACTICE CHANGES

On the original installations, the double-pass checker design was installed in Nos. 38 and 40 furnaces, and the single-pass checker design in Nos. 37 and 39 furnaces.

No difficulty was encountered during the early part of the first campaign on Nos. 38 and 40 furnaces, mainly due to the relatively low production and firing rates. However, as the operators gained furnace experience and as operating refinements continued to be made, it became more evident that the 2-pass checker design would require considerably higher maintenance while in operation and during down periods for rebuilding.

First campaign—No. 40 furnace concluded its first campaign on April 11, 1953, after having produced 368 heats—102,988 tons. Because of checker misalinement

caused by melting of the checker brick, it was necessary to replace hot pass checker work in both chambers from the rider arches up. It was believed that some of the hot pass checker difficulty could be alleviated by increasing the size of the vertical flue openings, which would result in higher gas flow through this chamber. This in turn would allow higher gas temperature at the point of entry to the cold pass. The checker brick in the cold pass showed no evidence of excessive temperature at this time; as a matter of fact, brick temperature was below 1300 F. Accordingly the flue openings were increased from 6 x 10½ in. to 10½ x 10½ in. During this campaign thermocouple readings were taken to determine checker temperatures. These temperatures ranged as follows for the period just prior to rebuilding:

Top of hot pass, F	2350 to 2450
Top of blind pass, F	1460 to 1580
Top of cold pass, F	1450 to 1560

First campaign—No. 38 furnace hot pass checkers began giving difficulty due to sagging of the checker work at approximately 300 heats of the first campaign. Before the furnace came down for a rebuild it was necessary to remove the top of the hot pass division walls to by-pass the first-pass checker, thereby allowing us to exhaust the remaining life in the roof brick. The furnace completed its first campaign on June 12, 1953, producing 408 heats—114,222 tons. The condition of the checkers at this time dictated complete replacement of hot pass checker work, 50 per cent replacement of divider walls and top replacement of the cold pass checker work. It was decided at this time that continued use of the double-pass design on two furnaces would set up an impossible situation with regard to maintenance and cost. The furnace was rebuilt with single-pass checkers having a 6 x 10½-in. vertical flue, open setting.

Second campaign—No. 40 furnace started its second campaign on April 20, 1953. After approximately 50 heats, the hot pass checker brick were starting to sag in both chambers. In order to try and retard this sagging condition, a high excess air practice was initiated. After the hot metal addition has been completed and the heat had settled down, the forced air fan was opened to 24,000 cfm or an excess air of 30 to 50 per cent depending on the oil input. This setting was held for the balance of the heat.

Approximateiy 50-F drop in checker temperature resulted from this practice; however, this was not sufficient. Damage to the brick continued and the productivity of the furnace continued to decrease because of progressively poorer draft. As the sagging and melting of checker brick continued, the high air practice was used from start charge-to-tap with no better results. The hot pass checker work in both chambers was completely melted and collapsed when the furnace came down for a light roof at 160 heats on July 15, 1953.

During the light roof, the following work had to be done on the hot pass section of each regenerator:

In the north hot pass checker, the top 8 ft-3 in. was replaced. Twelve courses of 40 per cent alumina brick were installed on top of the old brick and then topped off with six courses of 70 per cent alumina brick.

In the south hot pass checker, practically all checker brick were replaced, and the high alumina in the top 18 courses was installed. In addition, 19 rider arches were replaced.

Along with the installation of super duty high alumina brick, two air ports were added, one for each regenerator in the fantail inner slope wall. These ports measured 2 ft-4 in. sq and were opened and closed automatically in conjunction with the reversing dampers. The ports were so arranged that the door was open on the outgoing end, admitting cold air to the hot pass along with the exhaust gases. The firing practice set up for checker temperature control was as follows:

1. From start to charge throughout the heat cycle, 24,000 cfm air was used with a maximum limit of 750 gphr oil during the meltdown.
2. The air ports were used from start of charge throughout the heat cycle.

Eight thermocouples were installed, four in each hot pass chamber to aid in evaluating the effects of the air

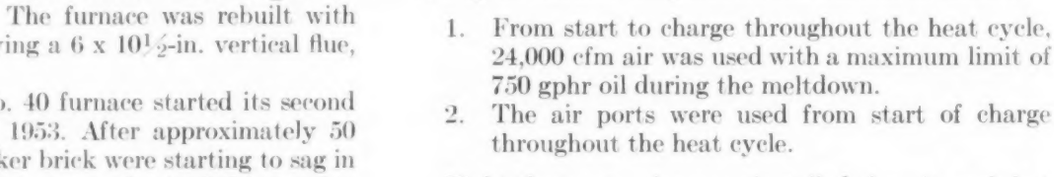

Figure 1 — Evaluation of the use of air ports was aided by thermocouples located as illustrated in the hot pass chamber.

TABLE I
Average Recorded Temperatures*

Average oil, gphr	Period of heat	Thermocouples							
		No. 1, F	No. 2, F	No. 3, F	No. 4, F	No. 5, F	No. 6, F	No. 7, F	No. 8, F
750	Melting scrap	1760	1620	1800	1900	2050	1940	1960	2140
550	Hot metal	1960	1820	1860	2000	2140	2040	2060	2230
550	Working	2110	1900	2080	2240	2310	2110	2160	2395
800									
620	Tap	2110	1910	2070	2160	2320	2160	2170	2380

* Firing south to north.

ports. The location of the thermocouples are shown in Figure 1. The average temperatures recorded by each thermocouple, throughout the different stages of the heat, are shown in Table I.

A short time later another temperature check was made, using chromel-alumel thermocouples. The temperature readings in the hot pass never ran higher than 2395 F in the second course of blow holes at the top of the chamber on the outgoing end, or lower than 1360 F on the bottom row of blow holes on the incoming end. These checks were made using the air ports and high air practice. After five heats had been checked, the accumulation of flue dirt on the thermocouple protection tubes was enough to affect the accuracy of the couples. Testing was discontinued at that time.

Inspection through the top row of blow holes while using the air ports and high air practice showed evidence of a cooling effect on the top checker courses over which the cool air was passing. This however, only affected that portion of the brick located along the wall in which the air port had been installed. Approximately one half of the chamber did not benefit from this cooling.

Use of the air ports together with high forced air practice produced a heavy blow on the charging floor elevation of the furnace which was only partially relieved by operating the draft control in the "open" position.

Due to blowing, the high air practice was discontinued at the time of the hot metal addition but the air ports were used from start of charge to tap. As a result of the amount of cool air entering through the air ports, a greater portion of flue dirt settled out in the form of a heavy deposit on the top checker courses, restricting the flow through the flues. At this time it was necessary to blow checkers at least once a week.

In Table II a comparison is shown of production data of No. 40 furnace for the month of June, 1953, prior to the light roof campaign where the high air practice was used, and the month of August, 1953, using the air ports and high air practice. The single-pass furnace average for the same periods is also shown.

The furnace ranked first in fuel consumption and first in tonnage for the month of June. The furnace ranked first in fuel consumption but dropped to third place in tonnage for the month of August. Seven more heats were made in August than in June and fuel consumption was 1.9 gal per ton less for August than June.

On September 11, 1953, the furnace came down for a light roof at which time the checkers appeared in fairly good condition. At this time it was decided to establish a maximum checker temperature limit of 2550 F. If and when this temperature was reached, the furnace would automatically reverse firing direction.

One month later, the checker brick in the hot pass was definitely starting to sag toward the baffle wall. At this time a combustion test indicated a high per cent of combustibles in the waste gas analysis. This condition could not be corrected even by running the forced air fan wide open (25,000 cfm). It was felt that the reason for this was that the hot pass flues had plugged preventing some of the air from reaching the hearth. During this period the high air and air port practice was still in effect. This sagging and melting down continued and the furnace started to blow very hard, making operation difficult.

On November 16, 1953, the furnace came down for its last light roof prior to rebuilding. Inspection of the checkers showed the following: the north hot pass was in very poor condition, having sagged approximately two ft from the top. This sagging was a result of melting of the courses of first-quality fire brick beneath the high alumina. The south hot pass showed very little sag. Both cold passes were in good condition. The high alumina top courses were in good physical condition. Due to the sagged condition in the north hot pass, the baffle walls were removed to a level of six courses below the top of the checkers, allowing the outgoing gas and incoming air an unrestricted flow path. It was felt that this would increase the ability to draft the furnace and bring the firing practice back to a more normal condition.

When the furnace came down for a rebuild on December 22, 1953, the following work on the checkers was necessary: the hot pass checkers and blind pass walls were completely replaced, the top six courses being 70 per cent alumina. The rider arches in the hot pass were replaced and the arch rise was increased from 9 to 15 in. In the cold pass chambers the top six courses

TABLE II
Production Data Comparison

	June, 1953		August, 1953	
	No. 40*	Shop average	No. 40**	Shop average
Charge-to-tap time, hr	11.56	10.92	11.25	11.01
Tap-to-tap time, hr	13.27	12.18	12.47	12.07
Charge-to-tap, tons per hr	24.38	25.82	25.14	25.46
Tap-to-tap, tons per hr	21.24	23.14	22.68	23.21
Total heats	52	48	59	60
Total tons	14,658	13,535	16,684	16,810
Oil per ton, gal	23.0	24.3	21.1	23.4

* High air practice.
** High air and air port practice.

TABLE III
Checker Data

	Furnaces	
	Nos. 37, 38 and 39	No. 40
Type of checker chamber	Single-pass, single chamber	Double-pass, single chamber
Total effective heating area above rider tile, sq ft	31,908	25,464
Maximum firing rate, gphr	750	750
Maximum air loading with theoretical air based on total exposed area, lb per hr per sq ft	1.99	2.64
Maximum air loading with theoretical air based on total effective heating area, lb per hr per sq ft	2.61	3.28

were renewed, the balance being in good condition.

During the rebuild, the checker chamber rayotubes were moved so that they were sighted down onto the roof of the checker brick rather than up onto the regenerator roof. It was anticipated that this change would yield a more realistic temperature measurement.

Third campaign—At the start of this campaign January 8, 1954, a special crew of checker blowers (three men) were assigned to No. 40 furnace. They worked five days per week, blowing checkers and hot pass tunnels and applied a chemical treatment to the top of the hot pass checkers.

A high air, high-pressure hearth practice was started at the beginning of this campaign. In addition, four of the best first helpers were assigned to this furnace in an effort to carry out this practice. It was expected to accomplish the following by this practice:

1. High air loading on checkers, decreasing checker brick temperature and resultant abuse.
2. Low hearth and checker infiltration, resulting in higher flame temperature, more complete burning of fuel and a lower rate.

The air loadings[1]* of regenerators at maximum fuel rates in typical Inland furnaces were calculated in an attempt to compare with the furnaces which B. M. Larsen[2] studied. These loadings are shown in Table III. Inland's loadings are rather high, but more important, the loadings are about the same in all three shops. The single-pass furnaces in this shop have the lowest loading and the double-pass furnace had the

* Numbers in parentheses refer to Bibliography at end of article.

TABLE IV
Practice—Third Campaign-No. 40 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1/ 7/54 to 1/12/54	650	20,000	5	23.7	30.2	2450
1/13/54 to 1/24/54	650	16,250	25	24.1	19.6	2450
1/25/54 to 2/12/54	650	22,500	41	25.0	20.5	2350
2/13/54 to 2/28/54	650	22,500	33	24.4	21.5	2400
3/ 1/54 to 4/ 8/54	750*	19,000				
	600**	22,000	79	23.9	22.6	2400
	600†	18,000				
4/11/54 to 5/31/54	750*	19,000				
	600**	22,000	111	24.0	22.2	2450
	600†	16,500				
6/ 1/54 to 8/22/54	750*	22,000				
	600**	22,000	176	26.04	20.8	2450
	600†	16,500				
8/23/54 to 11/30/54	750	No limit	214	27.95	19.2	2450
12/ 1/54 to 2/ 8/55	800	No limit	162	27.97	19.7	2450

* Period from melt down to finish hot metal.
** Period from finish hot metal to first ore addition.
† Period from first ore addition to tap.

TABLE V
Fourth Campaign-No. 40 Furnace vs Shop Average

	Fuel, gphr		Air, cfm		Total heats		Tap-to-tap, tons per hr		Gal per ton		Checker high temperature limit, F	
Month	No. 40	Shop	No. 40	Shop	No. 40	Shop	No. 40	Shop	No. 40	Shop	No. 40	Shop
1955												
Feb	800	800	24,000	24,000	23	56	25.55	26.29	25.5	24.3	2450	2500
Mar	800	800	24,000	24,000	71	59	27.37	25.55	21.0	22.3	2450	2500
Apr	800	800	24,000	24,000	67	68	28.52	27.90	19.5	20.7	2450	2500
May	800	800	24,000	24,000	77	66	30.48	27.45	19.1	21.2	2450	2500
June	800	800	24,000	24,000	68	66	29.17	27.41	20.1	21.0	2450	2500
July	800	800	24,000	24,000	66	61	29.10	25.53	21.6	22.7	2450	2500
Aug	800	800	24,000	24,000	70	66	29.28	27.66	19.3	21.3	2450	2500
Sept	800	800	24,000	24,000	71	70	29.65	29.11	20.7	20.7	2450	2500
Oct	800	800	24,000	24,000	59	61	29.20	27.88	19.8	22.3	2450	2500
Nov	800	800	24,000	24,000	69	62	28.14	27.91	21.3	21.4	2450	2500
Dec	800	800	24,000	24,000	67	68	28.45	27.28	20.8	22.3	2450	2500
1956												
Jan	800	800	24,000	24,000	73	62	29.01	26.44	21.1	23.4	2450	2500
Feb	800	800	24,000	24,000	20	67	28.90	28.82	21.5	21.2	2450	2500

TABLE VI
Practice—Fifth Campaign-No. 40 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to tap, tons per hr	Gal per ton	Checker high temperature limit, F
1956						
Feb, from the 19th	800	24,000	27	31.56	21.5	2450
Mar	800	24,000	78	31.17	19.3	2450
Apr	800	24,000	73	32.00	17.9	2450
May	800	24,000	74	30.15	21.0	2450
June	800	24,000	73	31.76	19.0	2450
July	Strike					
Aug	800	24,000	60	29.68	20.5	2450
Sept	800	24,000	72	30.95	20.1	2450
Oct	800	24,000	75	29.90	19.8	2450
Nov	800	24,000	60	30.97	20.4	2450
Dec	800	24,000	83	33.05	19.1	2450
1957						
Jan	800	24,000	73	31.46	20.1	2450
Feb	800	24,000	71	31.48	19.3	2450
Mar	800	24,000	74	32.33	19.6	2450
Apr	800	24,000	78	32.39	19.3	2450
May, to the 16th	800	24,000	41	31.60	19.4	2450

highest loading. This is somewhat unusual since 2-pass checkers are usually designed for lighter loads. Table IV shows the production data and firing practice for the entire third campaign.

A slight sagging in the north hot pass was observed the first part of May, 1954; however, the furnace was operating very well. No brickwork was necessary on the checkers until August, 1954. At this time five ft of brick were replaced in the south hot pass and eight ft in the north hot pass. By November, the north hot pass had sagged considerably, but the checkers could still be blown. The furnace was still drafting and running well.

The furnace came down for a rebuild February 8, 1955, at which time it was necessary to replace one half of the north hot pass and brace the rider tile. The south hot pass needed no replacement, however a slight sag was noted. The cold pass checkers were in good condition.

Fourth campaign—The benefit of the high air and

TABLE VII
Practice—Sixth Campaign-No. 40 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1957						
June	800	24,000	75	31.88	19.7	2450
July	800	24,000	78	32.35	17.8	2450
Aug	1000	30,000	61	28.18	19.9	2450
Sept	1000	30,000	65	29.01	21.7	2450
Oct	1000	30,000	68	30.99	21.4	2450
Nov	1000	30,000	73	32.42	19.9	2450
Dec	1000	30,000	62	29.76	21.3	2450
1958						
Jan	1000	30,000	5	30.32	27.1	2450
Feb	1000	30,000	70	31.77	18.9	2450
Mar	1000	30,000	68	32.10	20.0	2450
Apr	1000	30,000	74	33.13	18.7	2450
May	1000	30,000	64	31.57	20.4	2450
June	1000	30,000	49	31.75	20.0	2450
July	1000	30,000	38	31.48	19.5	2450
Aug	1000	30,000	69	29.85	20.9	2450
Sept, to the 3rd	1000	30,000	5	31.09	18.7	2450

TABLE VIII
Practice—Seventh Campaign-No. 40 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1958						
Oct, from the 12th	1000	30,000	45	30.80	18.5	2450
Nov	1000	30,000	64	30.72	18.4	2450
Dec	1000	30,000	73	31.93	18.8	2450
1959						
Jan	1000	30,000	67	29.02	19.5	2450
Feb	1000	30,000	61	28.99	21.2	2450
Mar	1000	30,000	63	30.11	19.0	2450
Apr	1000	30,000	55	31.43	19.9	2450
May	1000	30,000	71	30.35	19.7	2450
June	1000	30,000	60	27.53	20.8	2450
July	1000	30,000	32	31.02	18.5	2450
Strike—July 15 to November 7, 1959						
Nov	1000	30,000	37	30.13	22.2	2450
Dec	1000	30,000	74	32.01	21.2	2450

TABLE IX
Double-Pass Checker Calculations

	No. 40 furnace		Nos. 41, 42 and 43 furnaces	
	Present condition, 120 mm Btu per hr	Theoretical condition, 120 mm Btu per hr	Present condition, 180 mm Btu per hr	Theoretical condition, 180 mm Btu per hr
Hot pass checker openings, in.	9½ x 9½	9½ x 9½	9½ x 9½	9½ x 9½
Waste gas volume, at 2600 F, cu ft per sec	2320	2320	3310	3490
Total horizontal area to free area	1.733	1.733	1.733	1.733
Velocity, fps	11.25	9.0	9.85	9.0
Total horizontal area, sq ft	357	447	580	672
Checker width inside walls, ft	25.04	25.04	25.04	25.04
Hot pass length inside walls, ft	14.25	17.70	23.17	27.90
Horizontal free area, sq ft	206	258	336	388
Cold pass checker openings, in.	7½ x 7½	7½ x 7½	7½ x 7½	7½ x 7½
Free area, sq ft	144	173	137	259
Total area, sq ft	268	321	269	482
Velocity, fps	10.8	9	16.0	9
Cold pass length, ft	10.71	12.7	10.75	19.2
Blind pass length, ft (including walls)	5.0	5.0	6.08	6.0
Total length inside walls for 25.04 ft, width, ft	29.96	35.40	40.0	53.10
Total area inside walls, sq ft	750	893	1000	1304

TABLE X
Practice—First Campaign-No. 41 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1957						
Aug	1000	50,000	55	27.87	23.1	2500
Sept	1000	50,000	68	30.24	24.0	2500
Oct	1000	50,000	68	31.80	22.9	2500
Nov	1000	50,000	75	33.66	21.8	2500
Dec	1000	50,000	71	32.52	22.9	2500
1958						
Jan	1000	50,000	79	33.61	20.4	2500
Feb	1000	50,000	57	32.30	21.9	2500
Mar	1000	50,000	4	32.86	22.5	2500
Apr	1000	50,000	77	34.10	21.1	2500
May	1000	50,000	70	32.01	22.6	2500
June	1000	50,000	72	32.51	22.5	2500
July	1000	50,000	71	32.80	20.7	2500
Aug	1000	50,000	75	32.50	21.6	2500
Sept	1000	50,000	50	34.05	21.0	2500
Oct	1000	50,000	64	33.92	20.6	2500

high-pressure practice was continued throughout the third campaign of No. 40 furnace showing considerable improvement in productivity and a marked decrease in abuse to the checker work. Table V shows the practice and production data. The highest productivity to date was obtained in May, 1955, when a new monthly record was established: 22,556.8 tons and 30.48 tons per hr tap-to-tap.

As stated previously, the location of the checker radiation pyrometers was changed at the start of the third campaign so that they were sighted down onto the top of the checkers instead of at the checker roof. This did produce a more realistic checker temperature reading, the differential of the two readings being 125 F.

No brickwork replacement to the checkers was necessary during the fourth campaign from February 18, 1955, to February 17, 1956.

Fifth campaign—When No. 40 furnace was rebuilt in February, 1956, at the end of the fourth campaign, it was decided that the hot pass checkers would be completely replaced. All hot pass checkers were replaced with a chimney-type flue setting, with a 9½ x 9½-in.

TABLE XII
Practice—First Campaign-No. 42 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1957						
Aug	1000	50,000	54	28.58	24.1	2500
Sept	1000	50,000	66	30.87	23.8	2500
Oct	1000	50,000	77	33.74	20.9	2500
Nov	1000	50,000	66	31.71	22.9	2500
Dec	1000	50,000	71	32.38	21.2	2500
1958						
Jan	1000	50,000	9	32.34	29.6	2500
Feb	1000	50,000	70	33.48	22.1	2500
Mar	1000	50,000	73	33.09	22.3	2500
Apr	...	...	..	...	...	...
May	1000	50,000	29	31.10	24.6	2500
June	1000	50,000	74	33.26	21.8	2500
July	1000	50,000	69	31.88	22.2	2500
Aug	1000	50,000	73	32.96	21.8	2500
Sept	1000	50,000	64	33.68	22.2	2500
Oct	1000	50,000	70	32.80	22.0	2500
Nov	1000	50,000	68	30.58	22.8	2500
Dec	1000	50,000	37	30.92	26.6	2500

TABLE XI
Practice—Second Campaign-No. 41 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1958						
Nov	1000	50,000	54	30.61	23.5	2500
Dec	1000	50,000	74	31.96	21.6	2500
1959						
Jan	1000	50,000	69	31.78	21.7	2500
Feb	1000	50,000	63	32.10	22.1	2500
Mar	1000	50,000	77	33.65	22.4	2500
Apr	1000	50,000	65	32.50	23.4	2500
May	1000	50,000	77	33.29	22.2	2500
June	1000	50,000	55	30.39	23.7	2500
July	1000	50,000	32	31.72	23.0	2500
Strike—July 15 to November 7, 1959						
Nov	1000	50,000	51	29.54	27.5	2500
Dec	1000	50,000	70	33.70	21.2	2500

opening. At this time the checker brick used was first-quality firebrick. It was felt that the chimney-type flue would require much less cleaning maintenance during operation and yield higher preheated air due to the greater surface area of brick exposed to the outgoing gases and incoming air. At this time no replacement was necessary to the cold pass checkers; in fact, they looked excellent considering 2464 heats were on the checkers with only one topping off.

Table VI shows the production data for the fifth campaign. A decrease of 0.014 man-hr per ton checker cleaning maintenance has been realized with the chimney-type flue as only the top of the checkers can and need be blown. Upon completion of the fifth campaign in May, 1957, the only brickwork necessary was the top three courses of both hot pass chambers and eight courses in the cold passes. It was decided at this time that it would be necessary to replace the cold pass checkers completely at the end of the sixth campaign, sometime in May or June of 1958. In September, 1958, chimney-type flues were installed in the cold pass with a 7½ x 7½-in. opening. Tables VII and VIII show production data for the sixth campaign and the seventh campaign through 1959.

TABLE XIII
Practice—First Campaign-No. 43 Furnace

Period	Fuel, gphr	Air, cfm	No. heats	Tap-to-tap, tons per hr	Gal per ton	Checker high temperature limit, F
1958						
Nov	1000	50,000	42	32.01	21.1	2500
Dec	1000	50,000	73	32.12	22.0	2500
1959						
Jan	1000	50,000	62	30.31	23.1	2500
Feb	1000	50,000	70	33.78	22.6	2500
Mar	1000	50,000	71	32.11	22.7	2500
Apr	1000	50,000	72	33.90	21.5	2500
May	1000	50,000	63	32.33	23.0	2500
June	1000	50,000	73	32.89	21.5	2500
July	1000	50,000	34	33.06	21.5	2500
Strike—July 15 to November 7, 1959						
Nov	1000	50,000	52	30.65	24.8	2500
Dec	1000	50,000	72	33.87	21.1	2500

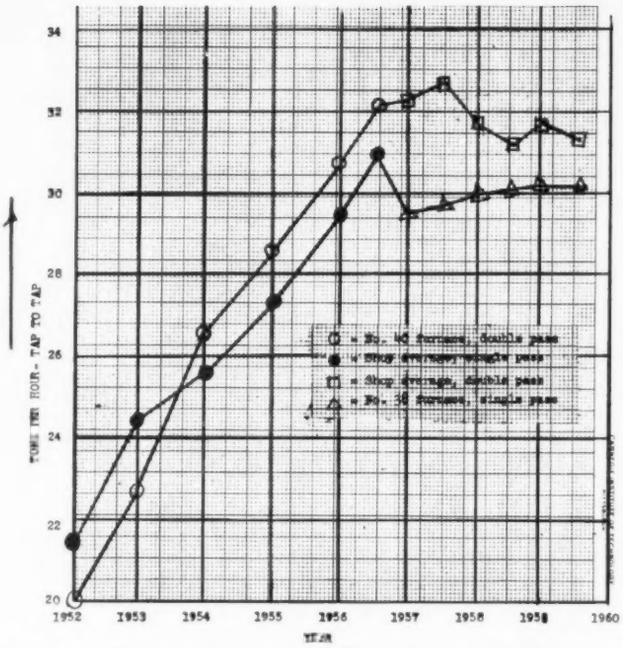

Figure 2 — The tons per hr rate of the double-pass furnace has increased with operating practice changes and design modifications.

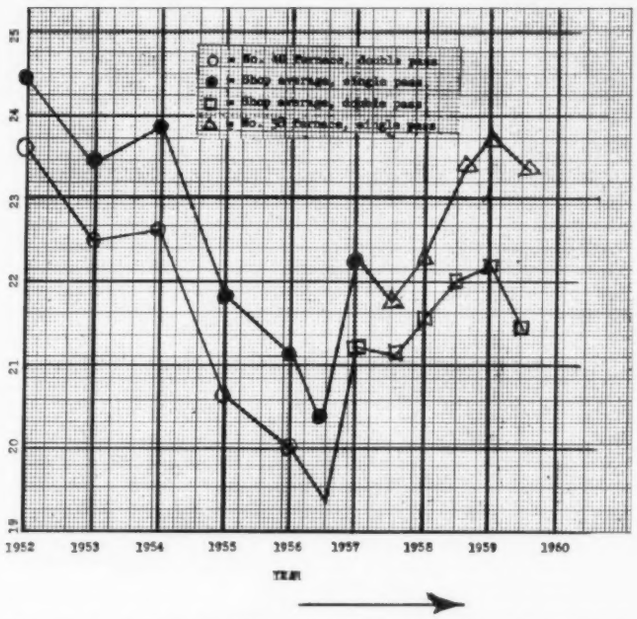

Figure 3 — The double-pass checker equipped furnace has a lower fuel rate (gal per ton produced).

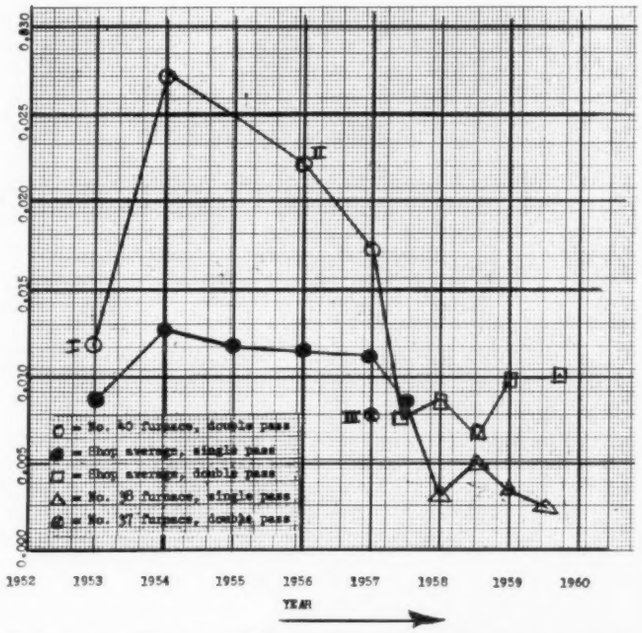

Figure 4 — The use of chimney-type checkers has greatly reduced required checker cleaning. I indicates the point when the crew of special checker blowers started. II indicates the point when chimney-type flues were installed in the hot pass. III indicates the cleaning required for both passes with the chimney-type flues (man-hours per ton).

Because of the improvements and the savings on fuel realized on No. 40 furnace, No. 37 furnace was rebuilt with double-pass checkers at the end of its fourth campaign in December, 1956. Chimney-type checkers were installed in both hot and cold passes. The hot pass flue opening is $9\frac{1}{2}$ x $9\frac{1}{2}$ in. and the cold pass $7\frac{1}{2}$ x $7\frac{1}{2}$ in. This furnace completed its sixth campaign in March, 1959, with no checker difficulty. Following this, No. 39 furnace was converted to double-pass checkers prior to the start of its sixth campaign in December, 1957. The same type flues were installed as in No. 37 furnace.

NEW FURNACE DESIGN

During the latter part of 1955, a decision had to be made as to checker design desired in the proposed three new furnaces. Calculations were made and are presented in Table IX. The basis for these calculations was taken from data secured from R. Knight of Kembla Steel Co. of Australia. The velocities recommended were worked out by the Australian steelmakers through trial and error and the final figures have proved successful in actual operations.

With the desired firing rate of 180 mm Btu per hr, it is noted that total area inside walls approximated 1304 sq ft. With the original four furnace building plans, it was believed impractical to design a furnace with this checker length. However, by redesigning and relocating the fantail flues and dampers, it was possible to increase the length of the checkers to 40 ft. Of this additional length of ten ft, one ft was added to the blind pass and nine ft were added to the hot pass.

The new furnaces have been in operation since August, 1957, and no problems with the checkers have arisen. Some of the critical dimensions of the new furnace checker system are as follows:

Inside length hot pass, ft-in.	23-2
Inside width hot pass, ft-in.	25-$\frac{1}{2}$
Inside length blind pass, ft-in.	3-10
Inside width blind pass, ft-in.	25-$\frac{1}{2}$
Inside length cold pass, ft-in.	10-9
Inside width cold pass, ft-in.	25-$\frac{1}{2}$
Checker volume, cu ft	15,370
Total checker depth, ft-in.	16-6
Type flue	Chimney
Flue size hot pass, in.	$9\frac{1}{2}$ x $9\frac{1}{2}$
Flue size cold pass, in.	$7\frac{1}{2}$ x $7\frac{1}{2}$
Distance from top of checker to roof, ft-in.	3-$9\frac{1}{2}$

Tables X, XI, XII and XIII show the production

data for the new furnaces through the end of 1959. No. 43 furnace did not start its first campaign until November, 1958. At the end of the first campaign on No. 42 furnace, a basic roof was installed.

SUMMARY

As indicated by the accompanying data, each successive campaign on No. 40 furnace has improved. It is felt that the major factors were the high air and high-pressure practice, the chimney-type checkers, establishment of maximum checker temperature and the improvement of operating techniques by furnace personnel.

Figure 2 illustrates the comparison of tons per hr for both types of checker chambers. As seen, No. 40 furnace produced at a lower rate than the shop until 1954. Since that time No. 40 furnace has produced at a higher rate than the single-pass furnaces, Nos. 37, 38 and 39. In addition, the three new furnaces have followed this same pattern. This is again evidence of the high-pressure, high air practice.

Figure 3 illustrates the comparison of gal of fuel oil per ton for both types of checkers. As seen, the double-pass checker has continually produced at a lower fuel rate. At present day cost of fuel, this is a considerable cost advantage.

Figure 4 illustrates the comparison of checker cleaning in man-hr per ton for both types of checkers. As seen, the double-pass checker originally required twice as much cleaning; however, since the installation of chimney-type checkers, a steady decline has occurred.

This history of checker design changes is an illustration of what can be accomplished by utilizing combustion principles along with refractory design changes and operating techniques. It has been through constant work on the part of production, combustion and management personnel that the problems encountered with the two original double-pass furnaces have been improved sufficiently so that the conversion of the two other existing furnaces was possible. The last single-pass furnace, No. 38, which was one of the original double-pass furnaces, will be reconverted to a double-pass furnace the next time checker replacement is necessary. This will then give a 7-furnace, double-pass shop.

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Discussion

PRESENTED BY

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L. O. SORDAHL, Bain Laboratory for Fundamental Research, United States Steel Corp., Monroeville, Pa.

Frank J. La Rocco and E. F. Pearson: Colorado Fuel and Iron Corp. has had no experience with double-pass checkers, but it is agreed that they should improve fuel efficiency if one has the room to install properly designed chambers.

Are the air ports still being used to cool the checkers? If so, is it possible this is necessary because the combustion of the fuel is not completed in the hearth and is still continuing in the uptakes and checker chambers causing excessive checker temperatures? The proper solution to this problem might be to improve the mixing of the fuel and air thus speeding up the combustion to where it is practically completed in the hearth.

F. D. Nelson: The practice of using the air ports has been discontinued. Currently periodic checks are run on the waste gas. In addition, a weekly inspection of the furnace system is performed by the general production and general labor foreman, test engineer and mechanical foreman. Emphasis is placed upon sealing to decrease air infiltration, checker cleanliness, flue cleanliness and slag pocket condition. Any areas that need attention are thus spotted and quickly corrected.

Frank J. La Rocco and E. F. Pearson: Are first-quality firebrick still used for the top of the hot pass setting? Also, it appears that the volume of the checker bricks in the setting was increased from approximately 28 per cent to 49 per cent or an increase of 75 per cent in heat storage and effective scrubbing surface by using the double-pass checker. Would the author care to comment on this?

F. D. Nelson: First-quality firebrick are still used for the top of the hot pass setting. When the flue setting was changed from an open to a chimney type, the volume of the checker bricks was increased from approximately 28 to 49 per cent.

Ivan D. Akey and E. Williams: The 2450-F limit on No. 40 furnace checker temperatures is compatible with ours, however, 2500 F is indicated as the limit for the

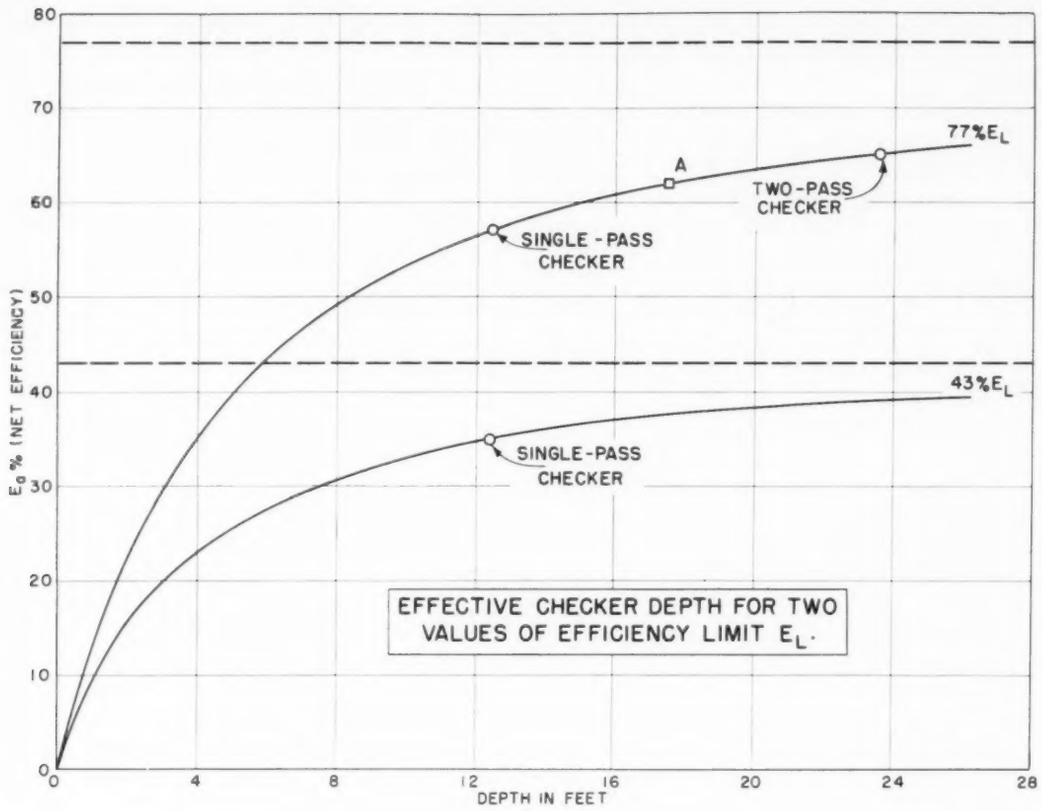

Figure 5 — Point A on the upper curve indicates the expected value of efficiency for the 2-pass checker involved, and the point of actual efficiency is noted.

newer furnaces. Is this because of the location of the temperature element, or is it because of brick characteristics?

At Great Lakes the checkers are washed once per week (twice per week on oxygen furnaces) with a high-pressure spray, 750 psig at the nozzle, which consists of four $\frac{1}{16}$-in. holes, using 70 gpm of water. Thus, the checkers are kept clean enough to allow a reduction of the openings from $7\frac{1}{2}$ in. sq to $5\frac{1}{2}$ in. sq. When No. 6 furnace was converted to an oxygen furnace, the checker opening was reduced to the $5\frac{1}{2}$ in. sq and, nearing the end of its first campaign, the results look very optimistic; however, it is felt that several campaigns will be necessary to permit accurate final determinations. Are chemicals still used in your checker cleaning?

It appears that the combustion air fan capacity was increased, were any corresponding changes made in the flue gas system (flues, stacks, boiler fans, etc.)?

The air consumptions which the author quoted indicate that there may be considerable generation of combustibles in the bath, would the author care to comment on this?

Are the maximum fuel rates adjusted to suit bath conditions? If so, on what basis, by a fuel profile, or by flue gas analysis?

Is the exposed surface of the checkers sufficient, with chimney construction, to preheat the air enough to give sharp flame characteristics instead of using additional air for this purpose?

Are the airports still used for controlling checker temperatures, or is the ratio between brick surface and flue gas velocity suitably balanced between the hot and cold passes to prevent overheating and damage?

F. D. Nelson: A slightly higher checker temperature limit is maintained on the new furnaces because of the larger hot pass checker chamber.

The use of chemicals for checker cleaning has been discontinued and now only live steam is employed.

The air fan capacity was increased from 30,000 cfm on the original four furnaces to 50,000 cfm on the three new furnaces. Flues were redesigned and boiler fans were increased to 160,000 cfm.

The fuel rates quoted were maximum rates and are adjusted dependent upon bath conditions at the discretion of the first helper and melter. On the new furnaces the maximum firing schedule is 1200 gphr during the charging period, 1000 gphr from finish charge to start hot metal and 800 gphr from start hot metal to tap.

The high air practice is being used during certain stages of the heat, as much as 50 per cent excess air. On the four original furnaces with maximum firing, this high an excess air cannot be reached with the present forced air fans.

B. M. Larsen and L. O. Sordahl: The only good reason for any checker design is the ability to preheat more lb of air per hr to a practical maximum of temperature. Practically all commercial furnaces are overburdened with respect to regenerator capacity.[3] That is, to our knowledge, there are no furnaces operated with enough regenerator capacity to preheat the air required for the fuel input used plus the air required for bath oxidation plus that required to burn the CO evolved from the bath reactions (especially in high-iron practice) up to a good approach to the practical maximum of temperature intensity. This is part of the reason why the use of pure oxygen in burners and lances has such a large effect on open hearth speed. And this is why any really more efficient regenerator design should increase

output and decrease fuel, so that the author's operating comparisons are pretty conclusive proof of higher efficiency for the 2-pass design.

Just the same, it is interesting to get a more direct measure of efficiency for these designs on actual operating furnaces, and such measurements have been made for three cases: (1) a single-pass design with a low "drift ratio" of 0.43 (high air leakage); (2) a similar single-pass design at a high drift ratio (low air leakage) of 0.77; and (3) a 2-pass design with the same low air leakage and drift ratio of 0.77. This term "drift ratio" is simply the ratio "heat capacity flow rate of air" divided by "heat capacity flow rate of combustion gases" and when multiplied by 100 is the efficiency of a perfect regenerator design under the flow conditions of any given test.

To compare the results in a simple manner, an arbitrary parameter called "effective checker depth" was adopted which is the abcissa scale on Figure 5. The ordinates are actual measured or calculated values of net regenerator efficiency.

The two curves shown are selected for the two values of drift ratio (or limiting efficiency, E_L here, in per cent) from a family of such curves calculated on an electrical analog computer,[4] the two here corresponding to the values of drift ratio which happened to exist in the tests. From the shape of these curves it can be seen that in order to obtain a net efficiency much closer to the ideal limit represented by the dashed lines would require an impractically large checker size in cross section or depth. The points marked "single-pass checker" here were obtained on two different furnaces, but these were almost identical in size and setting of checker work. So, if our arbitrary parameter has significance, both tests should indicate the same value of effective checker depth and it can be seen that both values come close to 12.5 ft (the actual checker work depth in these two cases was 14.0 ft). This is not a strictly rigorous treatment, but it comes close and it is felt that it gives an essentially true interpretation. The large difference in actual net efficiency (E_a) is due to a very large air leakage for the lower point and a very small air leakage for the upper one and illustrates the importance of a tight furnace system with good pressure control at sill level in the melting chamber.

Calculations and tests have shown that by far the largest single factor in the complex regenerator problem for a similar flow velocity range is the total of exposed or "wiped" surface over any given regenerator zone being measured. Now the 2-pass checker in this case naturally had a smaller flow cross section and much greater depth or total length of gas flow passage. It was also enough longer than the single-pass design to accommodate the blind pass and had small $5\frac{3}{4}$-in. flues in the cold pass so that its total wiped surface area for hot pass, blind pass and cold pass was much larger than in the single-pass design. The actual ratio of these areas for 2-pass over single-pass designs was 1.415. Using this ratio, the increase of wiped surface alone should have given an increase in effective depth from 12 ft-6 in. to 17 ft-8 in. or the point marked A on Figure 5. This would be an E_a value of 61.5 per cent but the measured value was 65 per cent corresponding to an "effective depth" of 23 ft-8 in. This difference of 3.5 per cent represents a close approximation to the true effect of the 2-pass design in terms of increase in mean heat-transfer coefficient caused mainly by higher flow velocity as well as increased turbulence. A gain of 3.5 per cent in efficiency may appear small, but it should be remembered that it is all "cream off the top" in terms of available high temperature heat and is therefore quite significant.

A few amplifying points in the author's paper would help, such as the thickness of checker brick and calculated values for total wiped or exposed surface areas in the regenerators, including the wiped surface of the blind pass and perhaps rider walls, listed separately. The air ports mentioned in his paper as being used in some early periods represent, it is felt, a very bad practice which tends to lower the true efficiency as well as interfere with draft control. Now that these furnaces are under good control, would it be feasible to use 5 to 6-in. flues in the cold pass with a minimum brick thickness to obtain an appreciably increased wiped surface area? It would seem that $7\frac{1}{2}$-in. flues in the hot pass would be ample with solid flue settings.

Member: In the graphs the authors presented several occurrences seem rather unusual. In July, 1956, the tons per hr reached a maximum, and then dropped down and leveled off and the oil consumption reached a minimum, and then went back up a little and leveled off. Was there some reason for that?

F. D. Nelson: The addition of the three new furnaces with accompanying new personnel and start-up problems has some effect. In addition, in order to have a more consistent firing practice on all seven furnaces, the firing rate on the four original furnaces was increased to 1000 gphr maximum. ▲

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Limitations of Blast Furnace Stoves

by T. R. SCHUERGER
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. . . . in order to accurately design blast furnace stoves to meet the challenge of new technology requiring higher blast temperatures (i.e., improved burden and natural gas injection) available data on existing stoves must be examined and additional data obtained. This data could be employed in furthering research to determine a compatible analog for the blast furnace stove.

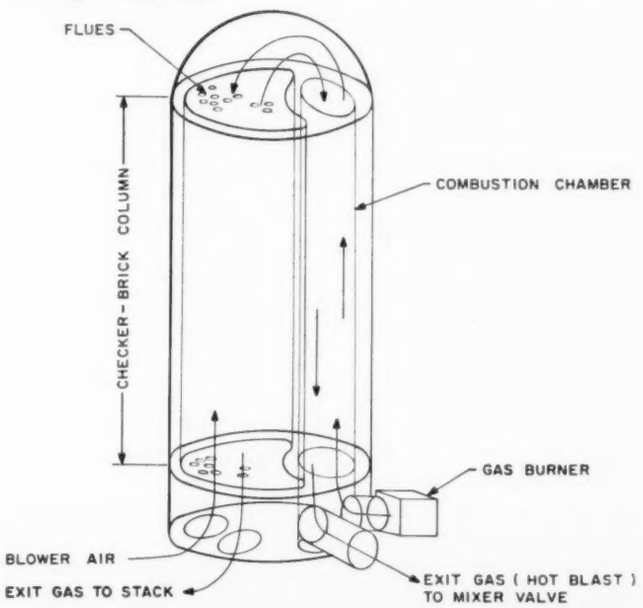
The analog could then be programmed for digital computation to produce a general solution with suitable design parameters for the complex mathematical equations which describe regenerative thermodynamics . . . .

IN the last few years, considerable effort has been expended by various groups to learn more about the operation, general performance and design of blast furnace stoves. New blast furnace operating techniques and the use of higher percentages of beneficiated ores indicate that higher straight-line hot-blast temperatures, perhaps about 2000 F or higher, can be effectively used in blast furnaces and may actually be required for proper performance of the furnace. In present-day operations, the straight-line hot-blast temperature rarely exceeds 1600 F; therefore, the effort to learn new and better ways to design and operate blast furnace stoves is aimed at finding means to get higher hot-blast temperatures from existing stoves and determining methods of designing more efficient stoves so that they do not become too large and too costly.

The present discussion deals with some of the limitations of blast furnace stoves which may be categorized by: (1) there are limitations in the physical systems, that is, in the structures and materials of the stoves; (2) there are limitations in design knowledge, that is, in the knowledge of how to design the most efficient type of stove; (3) there are certainly limitations in the ability to always operate stoves efficiently; and (4) there are limitations in the knowledge of the theory of stoves, and regenerative heat exchangers in general.

The stove itself is a tall cylindrical structure with a steel shell and an inner refractory lining. Figure 1 shows diagrammatically a present-day 2-pass stove, which is about 25 ft high and 25 ft in diameter. Top gas from the blast furnace is burned in the stove

Figure 1 — Schematic diagram illustrates gas and air flow through the stove.



combustion chamber to heat the checker bricks, which are the heat-storage elements in the stove. The gas is mixed with air in a burner at the base of the stove and combustion takes place in the combustion chamber. The hot combustion gas flows up the combustion chamber and down through the checker-brick column during the heating cycle.

During the cooling cycle (when the stove is on blast) cool air from the blowers is passed through the stove from bottom to top, down through the combustion chamber, through a mixing valve, and into the hot-blast main, which conveys the heated air to the blast furnace. The cool blower air is heated during passage through the stove, and as time on blast increases, the exit air temperature decreases. Since the blast furnace under normal operating conditions uses a constant volume of wind at a constant temperature, a temperature-sensing device in the hot-blast line regulates valving so that the cool blower air is properly proportioned between the stove and the by-pass line to give the desired straight-line hot-blast temperature. During the cooling cycle the stove releases heat at a constant rate.

Regarding the limitations in the physical systems, it is known that refractory bricks have temperature limits and are subject to alkali corrosion. The steels that are used for supporting the checker-brick column in the stove have temperature limits, and the fuel that is burned in the stove (blast furnace top gas) has a theoretical flame temperature of approximately 2600 F. These temperature limits on the physical system impose limiting values of output temperature that may be expected from the stove. In other words, with the existing types of fuel it is physically impossible to obtain a straight-line blast temperature in excess of 2300 or 2400 F from a stove. Most refractories presently in use are acceptable for use to 2100 or 2200 F, and some companies are now considering or using refractories that should be good to 2300 or 2400 F. The limitations of the physical systems can only be overcome through the development of improved materials.

Regarding the limitations in knowledge of the design of blast furnace stoves, one of the most significant items is the thermal capacity, or stove size, that is required for producing a specified hot-blast temperature at a specified blast volume. After years of experience in the design and construction of blast furnace stoves and from thermodynamic studies that have been made, usable design formulas have been developed. However, it is still generally believed that stoves may be overdesigned. Overdesign of facilities generally occurs when the designers are not too certain of their aims, or when they do not have the exact formulas or criteria for design. Another limitation in the design of stoves is the specification of the firing capacity or burner capacity required for specific hot-blast volumes and temperatures. These will be discussed later.

In the operation of stoves, questions arise: (1) what is the minimum firing rate required for a specified hot-blast temperature at a specified volume; (2) what cooling rate or on-blast time is required for most efficient operation; and (3) what cyclical frequency or ratio of on-heat to on-blast time is required for most efficient operation of the stove?

In all these practical categories of the physical system, the design and the operation of the stove, there are many limitations. Construction costs and fuel costs are becoming higher, and the need of increased hot-blast temperatures is becoming more and more significant. Therefore, it is desirable to improve or push forward the limits imposed on the present types of blast furnace stoves which can be built and operated.

THEORY OF REGENERATORS

One approach to a solution of the design and operating problems is a more intensive study of the theory of regenerators. The regenerative type of heat exchanger has been subjected to extensive treatment during the last 30 years, but the solution of the complex mathematical equations describing the thermodynamics of regenerators has only recently aroused interest. This interest came about largely as a result of new applications of the regenerative heat exchanger, such as the rotary regenerator considered for use in automotive gas turbines and the pebble-bed regenerator for wind-tunnel application, in which simulation of flight stagnation temperature is necessary. Furthermore, the same type of mathematical differential equations are encountered in mass transfer problems in the chemical industry.

By proper application of the first law of thermodynamics, two differential equations, which describe the thermodynamics of the regenerative system, can be written.[1, 2]*

$$MC\frac{\partial T}{\partial t} = hA(\theta - T) \qquad (1)$$

$$mc\frac{\partial \theta}{\partial t} = WLc\frac{\partial \theta}{\partial x} - hA(\theta - T) \qquad (2)$$

where:

T = Checker-brick temperature, F
θ = Heating or cooling-fluid temperature, F
t = Time, hr
x = Vertical distance in the stove
M = Mass of brick in the stove, lb
m = Mass of fluid in the stove, lb
C = Specific heat of the brick, Btu per lb, F
c = Specific heat of the fluid, Btu per lb, F
L = Length, or height, of the stove, ft
W = Mass flow rate of the fluid, lb per hr
h = Over-all heat-transfer coefficient, Btu per hr, sq ft, F
A = Heating-surface area in the stove, sq ft

These equations include all the significant parameters and variables in a blast furnace stove system. It may be noted that the mass of brick in the stove appears in the equations as well as the heating-surface area, the over-all heat-transfer coefficient, the specific heat of the brick, the brick and gas temperatures, the weight of the gas in the stove, the mass flow rate of the gases in the stove, the length or height of the stove column and the specific heat of the gases passing through the stove.

Present-day analyses indicate that these equations can be used to describe accurately the performance of a

* Numbers in parentheses refer to Bibliography at end of article.

given stove, provided the right numbers are used for parameters in the equations. These equations can also be developed by using the more standard energy balances. The solution of the differential equations has been dealt with by: Nusselt;[3] Anzelius;[4] Schumann;[5] Furnas;[6] Carslaw and Jaeger;[7] Amundson;[8] Churchill, Abbrecht and Chu;[9] Coppage and London;[10] Jacob;[11] and Dabora.[12] The solutions of both equations are of a purely analytical nature and assumptions are generally made in terms of the ratios of the heat-transfer coefficients during heating and during cooling. The solutions are generally derived for certain ratios of heating and cooling times, and for purely analytical solutions, results can be derived for only a single heating or cooling cycle. These purely analytical solutions are generally of no direct use in the actual design or operation of blast furnace stoves.

However, considerable work has been done with numerical solutions of the equations, as well as with approximate heat balances for blast furnace stoves. During the last 30 years much literature has also been published about design criteria for regenerators. Some of the authors are Rummel,[13] Mohr,[14] Hausen,[15] and Heilingenstandt.[16] In addition to these publications, which deal primarily with the theoretical or near theoretical aspects of regenerator design, many of the companies using and building regenerators have developed their own design criteria based on experience and performance data along with some assistance from the theoretical work. However, it can be stated that a general solution for the exact differential equations describing the thermodynamics of the blast furnace stove has not been developed, and consequently, no general design data or operating requirements are available.

Certainly in 90 or 100 years of operation of regenerative blast furnace stoves, much has been learned from a practical point of view about stove design and general operation. If more improvements are to be made, it might logically be assumed that they can be made through more intensive treatment of the theory or through the critical use of more intensive (or exact) test and operating data.

The United States Steel Corp.'s applied research laboratory has considerable interest in the development of improved designs and improved methods of operating blast furnace stoves. The laboratory has been working on a 2-phase program designed to increase the present knowledge of stoves. One approach to solving the stove problems is a solution of the mathematical equations (1) and (2). Another approach is a more intensive gathering of operating field data and a critical analysis of these data to learn about improving regenerator performance. The first approach, that of an analytical program for the solution of the mathematical equations that describe the regenerator, is being implemented through the development of an analog for the blast furnace stove. A proper analog of a blast furnace stove can be used for laboratory studies of the stove dynamics. Stove dynamics can be defined simply as the heating and cooling rates of a stove for stated gas and air rates and stated stove parameters: checker-brick mass, exposed surface area, checker-brick thickness and thermal constants. Dynamic analysis is one way to evaluate stove design and stove performance. Extensive dynamic

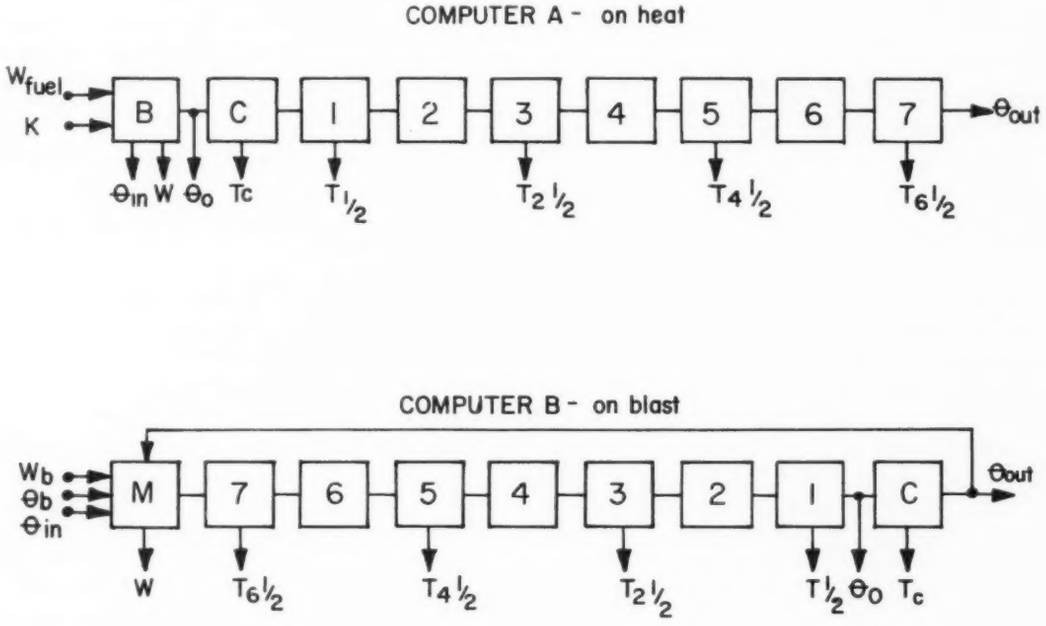


Figure 2 — The use of two computers will facilitate the use of different heat-transfer coefficients.

CODE:
B - BURNER SECTION
M - MIXER-VALVE SECTION
C - COMBUSTION CHAMBER, DOME SECTION
→ INPUT, OUTPUT
↓ READ-OUT
1,2,3,··· = CHECKER SECTIONS

analyses can seldom be performed entirely in the field.

COMPUTER STUDIES OF REGENERATORS

Electrical analogs have been successfully used on many occasions for simulating the transfer of heat and for simulating complete heat-exchanger units.[17, 18] In some electrical analogs, electrical resistors are used to represent thermal resistance and electrical capacitors are used to represent thermal capacitance. In recent years, universal computers, sometimes called operational analogs, have become available. These computers can be easily programmed for the simulation of a variety of physical problems. To program an analog, analogous relationships must be established between the physical media (in this case the thermal media) and the computer media. The common language between the media selected for this problem is a mathematical model of the stove that consists of equations (1) and (2).

The thermal analog of the stove, like the stove itself, is made up of four basic elements:

1. A checker system for heat storage.
2. A combustion chamber and dome system for a limited amount of additional heat storage.
3. A burner that establishes a combustion gas temperature and mass flow rate on heat.
4. A mixer valve that establishes air mass flow rate on blast.

To simplify the checker system analog the following assumptions are made:

1. The temperature and flow distribution on horizontal cross sections of the stove are uniform.
2. External heat losses through the insulating walls of the stove are negligible.
3. Vertical heat flow through the mass of the brickwork is negligible.
4. Conduction, convection and radiation heat-transfer coefficients for the checker brick may be combined and specified as an over-all transfer coefficient, this being the h that appears in equations (1) and (2).

Because of the nature of the universal analog computer, it is necessary from a mathematical point of view to regard the checker column as divided into a number of segments. Figure 2 shows a block diagram schematic of the thermal analog of the blast furnace stove. Two somewhat identical computer programs are shown. Computer A is the on-heat program with a burner section, a combustion chamber-dome section and seven checker sections. Computer B is the on-blast program with a mixer-valve section, seven checker sections and a combustion chamber, dome section. The general arrangement of computers A and B is similar, except that B is the reverse of A (the fluid flows in a reverse direction on blast). The use of two computers for the analog study also facilitates the use of different thermal constants for the on-heat and on-blast portions of the computer simulation. The on-heat fluid contains CO_2 which radiates heat well at high temperatures, and the on-heat, heat-transfer coefficient is larger and has a different functional relationship than the on-blast coefficient. Previous experience has shown that seven checker sections and one section representing the combustion chamber dome are adequate for computer simulation.

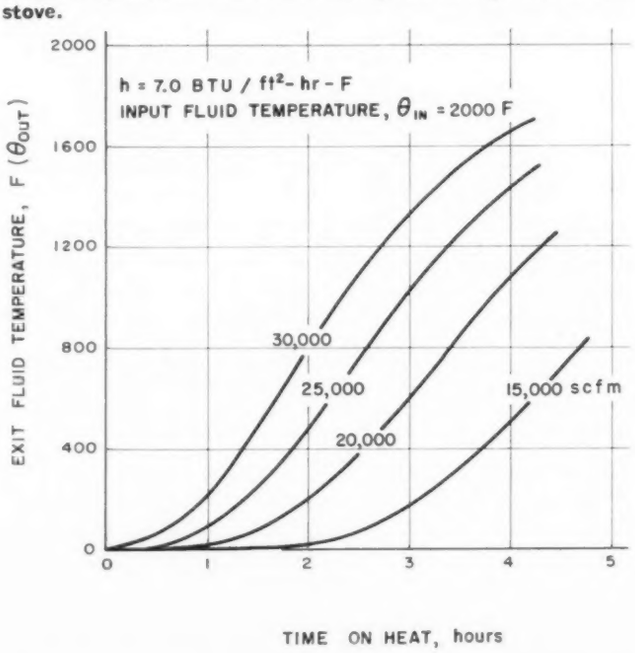
Operation of the analog consists in setting dials for the desired burner fuel input (W_f) and actual air-fuel ratio (K) in computer A, and in setting dials for the desired blast volume (W_b) and blast temperature (θ_b) in computer B. Dials in a timing circuit are set for the desired time on heat (t_h) and the desired time on blast (t_b). Constants for the stove geometry and the thermal parameters, that is, specific heats and heat-transfer coefficients, are set into each section of computers A and B.

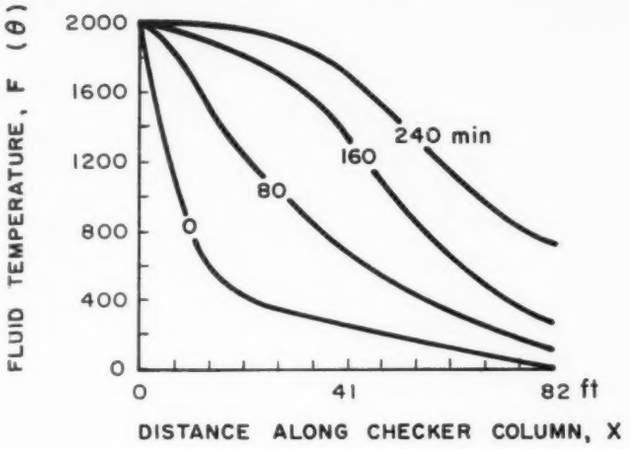
A necessary first phase of any study program such as this is a verification of the validity of the analog. This verification can be accomplished in many ways. One way is by operating the simulator much as a real stove would be operated and determining whether the heat balances from on heat to on blast check one another. Another, and very practical way of checking the validity of the analog, is a comparison of the operation of the analog with data gathered in the field. Both these techniques were used to verify the analog and preliminary results have been quite satisfactory.

Much work has gone into the development of the analog program since its origination in 1957, and considerable work has gone into the gathering of field data for use in comparing analog results.[19] Some of the preliminary computer results will be presented.

In the early work many studies were made to observe the effect of heat-transfer coefficients and mass flow rates on the general performance of the blast furnace stove analog. Some results of this work are shown graphically in Figures 3, 4 and 5. For this work a fluid input temperature of 2000 F was used for all the computation while the stove was on heat. A fluid input temperature of 0 F was used while the stove was on blast. Figure 3 shows the effect that increasing the firing rate at a constant temperature has on the exit-fluid temperature or stack-gas temperature, with the

Figure 3 — Analog computations were made of the exit-fluid temperature while increasing the firing rate of the stove.





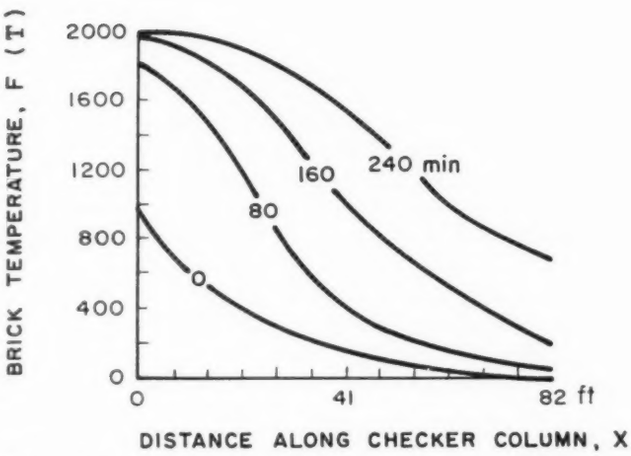
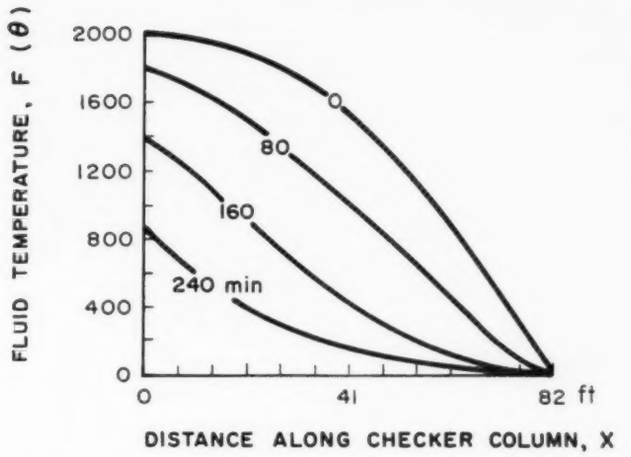


Figure 4 — Cyclic on-heat calculations were made until a repetitive temperature was reached.



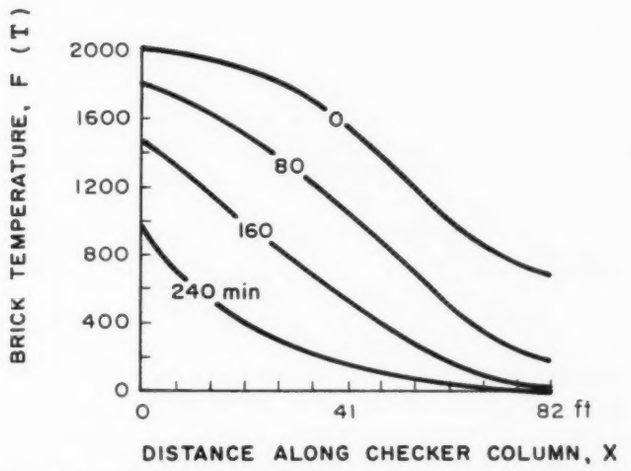


Figure 5 — A maximum fluid temperature of 2000 F was used in the calulations.

assumption of a constant heat-transfer coefficient of seven Btu per sq ft, hr, F. These data are for a single heating cycle in which the temperature of the brickwork was 0 F at the beginning of the cycle. The data in Figures 4 and 5 were obtained for a cyclical condition. A symmetrical cycle with identical times of four hr, identical fluid flow rates (15,000 scfm) and identical thermal constants (seven Btu per sq ft, hr, F) for both the heating and cooling cycle was used during this study. Height of the checker column in each case was 82 ft. Brick temperature at the end of a heating or cooling cycle is the initial brick temperature for the succeeding heating or cooling cycle, just as in the operation of a real stove. At the beginning of the cyclical operation, brick temperature was 0 F and the cycling was conducted until a repetitive temperature cycle was observed.

These preliminary studies indicate how the analog can be used to study the effects of heat-transfer coefficients and fluid flow on stove performance. The cycling test also showed that the analog could be operated in a manner similar to the way a stove is operated in a field. The shapes of the curves in Figures 4 and 5 are similar to the shapes of temperature curves determined by measurement in operating stoves. Exact similarity is not expected for this data because constant, estimated heat-transfer coefficients were used in the study. Real heat-transfer coefficients can be determined within nominal engineering accuracy by using the analog in conjunction with data from field studies. If brick temperature distribution, input and exit-fluid temperatures and fluid flow rates are known for an operating stove, sufficient data are available to match the analog to the operating stove. Heat capacitances are known for the temperatures encountered in the stove. If the analog is operated at the input-fluid temperature and flow rate required for the real stove, the only thermal constants that need be matched to the real stove are the heat-transfer coefficients. These coefficients can be empirically varied on the analog until brick temperature distribution and exit-fluid temperature on the analog match those measured in the operating stove.

After the preliminary work on the analog program was completed, the analog study was focused on the development of an exact model that might be able to best reproduce the operation of a blast furnace stove under its true cyclical operating conditions. This is the only way a true dynamic model of the stove can be established. A dynamic model has been developed that will reproduce actual operating conditions under the condition of cyclical operation to within a nominal accuracy of ten per cent of a real stove, that is, ten per cent within the limits of accuracy of the measurement of field data. The present objective of the laboratory is to develop an analog that can

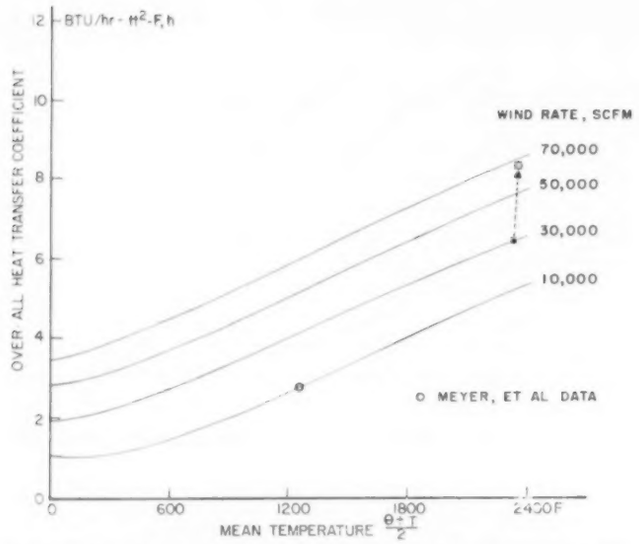


Figure 6 — Over-all heat-transfer coefficients were calculated from theory.

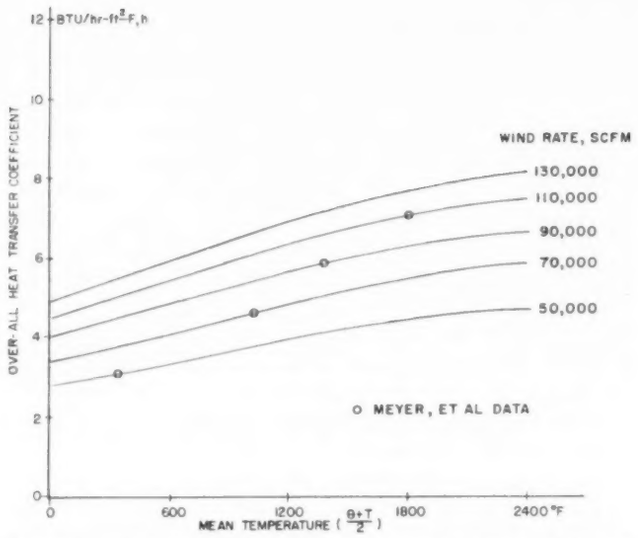


Figure 7 — Empirical data points seem to agree with the calculated data.

reproduce field data within a nominal one to two per cent. An analog of this accuracy should provide the general solution that is being sought for the regenerative heat-exchanger equations.

The simulator with ten per cent accuracy is not yet suitable for providing good design and operating data. However, concerted effort on the development of the analog has provided some verification of many important aspects of a solution of the stove problem. It has been shown that the variable nature of the heat-transfer coefficients, that is, the heat-transfer coefficients written as functions of both temperature and mass flow rate, is quite important. It has also been shown that the cyclical operating condition of the stove when the stable cycle is reached is independent of the initial conditions, the initial brick temperatures at the beginning of the cyclical operation. There are also indications that the combustion chamber and dome of the stove do not contribute appreciably to the heat storage capacity of the stove. With the analog, it has been shown that after a change has been made in the stove-operating conditions, as many as 25 operating cycles may be required to reach a new condition of cyclical stability.

HEAT-TRANSFER COEFFICIENTS

To have initial values of heat-transfer coefficients for the analog computer study work, heat-transfer coefficients were calculated from theory. These calculated heat-transfer coefficients for Kennedy checkers and 92-Btu blast furnace gas for on-heat conditions and for air on-blast conditions are shown in Figures 6 and 7. These are over-all heat-transfer coefficients, which take into account heat transfer by conduction, radiation and convection. Conductive heat transfer takes place in the checker brick. The convection coefficient is the air or gas film heat-transfer coefficient. The data in Figures 6 and 7 were calculated from standard formulas for radiation and from the Seider-Tate equations for convective heat transfer in smooth pipes. Work to date indicates that these calculated heat-transfer coefficients are probably fairly good.

In some analog computer studies of blast furnace stoves that have been previously reported,[20] heat-transfer coefficients were empirically determined as a function of the mass flow rate of fluids but not as a function of temperature. These empirically determined heat-transfer coefficients are plotted on the calculated data presented in Figures 6 and 7. This analog computer work involved working with only single heating and cooling cycles and did not attempt to reproduce actual stove operation under cyclical conditions, but it is interesting to note that the empirical data falls on the graph lines. The majority of this work appears to have been done for flow rates on heat of the order of 10,000 to 30,000 scfm and for flow rates in the range of 70,000 to 90,000 scfm on blast. The empirical results fall in the range of 1200 to 1500 F on the temperature scale. This range is probably a good average temperature for the blast furnace stove. These results might be considered to further confirm the calculated heat-transfer coefficients.

As mentioned previously, several important conclusions regarding stove performance have already been drawn from the analog work. The study is progressing in a very encouraging manner.

EXPERIMENTAL FIELD WORK

The first consideration in the experimental field work is heat storage in the stove from a very general point of view. Heat storage in the stove is defined as the heat the stove can release at a constant rate to maintain constant temperature in the total blast. The variables that determine the heat storage in the stove are:

1. Heat input per min and duration of the heating cycle.
2. Total mass of the brick and type of brick.
3. Height and diameter of the stove.
4. Heat-transfer rate and temperature distribution in the checkers.
5. Dome and stack temperatures.
6. Thermal efficiency.

The heat input per min is determined by the burner firing rate and the Btu value or heat content of the burned gas. To absorb the heat released in the com-

TABLE I
Data on Carrie No. 6 Stoves*

Burner rate, cfm	Length of heating cycle, hr	Wind rate, cfm	Hot-blast temperature, F	Time on blast, hr
7,000	3.75	60,000	1050	2
10,000	3.00	63,000	1100	2
13,000	2.50	65,000	1150	2

*** 180,381 sq ft of checker heating surface and 1,803,810 lb of checkers per stove.**

bustion chamber, the proper mass of brick must be available. Inasmuch as dome and stack temperatures must be controlled because of mechanical and structural reasons, the thermal properties of the brick and the physical configuration of the brick in the stove must be such that maximum heat transfer from the hot combustion gases to the brick can occur quickly. The maximum allowable stack temperature, radiation losses and per cent of excess air in the flue gases determine the thermal efficiency.

All these variables determining the heat storage are interrelated in complex equations that are not completely solved at the present time. However, the heat storage in a stove is related to the firing rate and thermal efficiency. The data obtained on the Carrie No. 6 furnace stoves (Table I) confirm this relationship, as shown in Figure 8. The heat storage in these stoves, expressed as Btu per lb of brick, is plotted against the heat input per min per sq ft of heating surface multiplied by the thermal efficiency. The heat stored per lb of brick increases as the heat input per min increases because the heat input alters the temperature profile in the stove.

The second major factor of interest is the amount of time a blast temperature can be sustained when the stove releases heat at a constant rate. Some of the important variables that determine this factor are as follows:

1. Wind rate.
2. Maximum dome and stack temperatures.
3. Time cycle of the stoves (time on blast plus time on heat).
4. Heat stored in the stove.

Wind rate depends upon the blast furnace requirement, and the stove must be able to heat the desired volume of wind. The maximum dome temperature is limited by the refractories used. With the recent improvements in refractories, it is now possible to consider dome temperatures as high as 2400 F. The maximum permissible stack temperature is governed not only by the mechanical and structural considerations, but also by the thermal efficiency of the stove system. As shown in Figure 9, the thermal efficiency of the stove system decreases as the stack temperature increases. Accordingly, operating the stoves at high stack temperatures will result in increased operating costs. The thermal efficiency also affects the capacity of the required burner, which is discussed later.

The time cycle, the heat storage in the stove and the number of stoves are interrelated. However, from practical considerations, it is undesirable to have too short an on-blast, on-heat cycle because of the time lost in manipulation of the various valves. Even with completely automatic stove changing, a 30-min on-

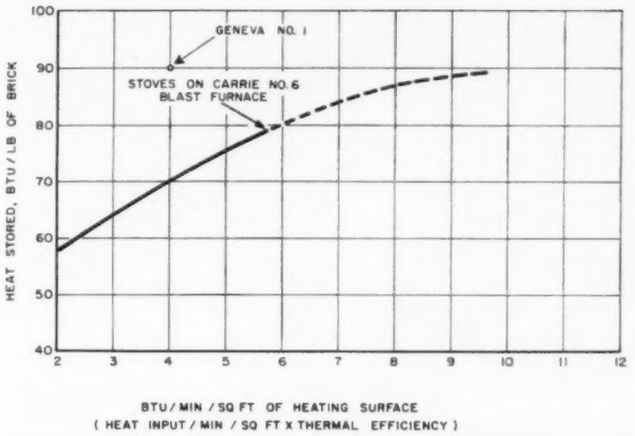


Figure 8 — A relationship between the firing rate and the heat stored was determined.

blast cycle is probably the minimum that should be considered. An on-blast cycle longer than one hr is also undesirable because it will lower hot-blast temperature with present stove construction.

The number of stoves in a blast-heating system cannot be less than two, because one stove must be on the heating cycle and the other on the blast cycle; however, from practical considerations, the number should not exceed four.

TABLE II
Stove Design Nomenclature

R	= Ratio: flue gas to gas
C	= Mean specific heat of refractory
c_g	= Mean specific heat of flue gas
c_a	= Mean specific heat of hot blast
d	= Hydraulic diameter
A	= Total heating surface in stove
A_f	= Total flue cross section in stove
f	= Function
a	= Area of one checker opening
e	= Natural logarithm
t_h	= Time on gas
t_b	= Time on blast
H	= True heat transfer
H_1	= True heat transfer (revised)
H_2	= Theoretical heat transfer
s	= Checker wall thickness
B	= Circumference of checker opening
u	= Function
W_f	= Required gas volume
W_s	= Flue gas volume
W_b	= Blast volume
v	= Function
E_g	= Water equivalent of flue gas
E_b	= Water equivalent of blast
S_s	= Velocity of flue gas in checker opening
S_b	= Velocity of blast in checker opening
x	= function
y	= Function
h	= Total heat-transfer coefficient, flue gas
h_1	= Total heat-transfer coefficient, flue gas dome
h_c	= Convection heat-transfer coefficient, flue gas
h_c'	= Convection heat-transfer coefficient, blast
h_{sm}	= Mean radiant heat-transfer coefficient
p	= Specific weight of checker mass
θ	= Temperature change, flue gas in dome
θ_1	= Temperature change, flue gas in stack
θ_2	= Temperature change, hot blast
T_d	= Temperature change, top checkers
θ_s	= Flue gas temperature, inlet
θ_s'	= Flue gas temperature, outlet
θ_b	= Blast temperature, inlet
θ_b'	= Blast temperature, outlet
T_a	= Mean checker temperature, dome
y	= Thermal conductivity, checker
n_B	= Efficiency of brick
n_H	= Efficiency of heating surface
n_{st}	= Efficiency of stove

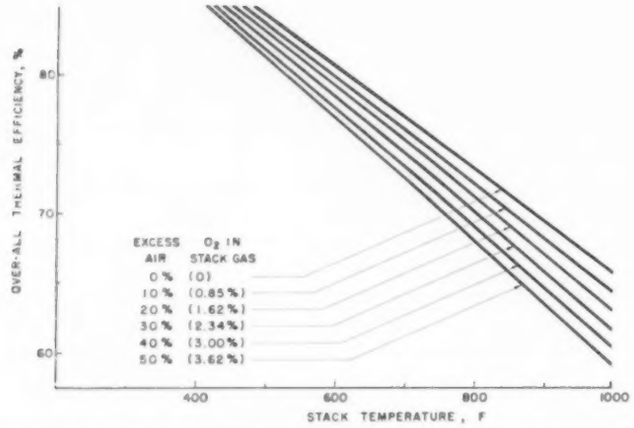


Figure 9 — The theoretical thermal efficiency decreases as the stock temperature is increased.

STOVE RATIO

To correlate the available stove, heat-storage data from the different sources, a new term, "stove ratio," has been coined; this is defined as the ratio of the heat extracted per min from the stove to the heat input per min multiplied by the thermal efficiency, see Figure 10. This stove ratio also indicates the ratio of on-heat time to on-blast time for a particular wind rate and firing rate. If the stove ratio is significantly larger than one, heat is being extracted from the stove at a faster rate than the input rate. Therefore, the heating period will be proportionately longer than the heat-withdrawal period. Accordingly, more than two stoves would be required, because at least two stoves would be required for the storage of heat while one stove is on blast. This type of operation will be called a "2-off, 1-on" cycle. When the stove ratio is less than one, a 2-stove system or a 4-stove system in which two stoves on blast and two stoves on heat operate simultaneously will be adequate. This cycle will be called a "1-off, 1-on" cycle. Note that the stove ratio will decrease as the heat input per min or the firing rate increases. The available data indicate that the stove heat storage, expressed as Btu per lb of brick, increases as the stove ratio decreases and reaches an optimum of 75 Btu per lb of brick for a stove ratio of approximately 1.2.

Below the 1.2 stove ratio or for a 1-off, 1-on cycle, the stove heat storage decreases, which is consistent with the heat-transfer fundamentals because the 1-off, 1-on stove cycle inherently implies extremely high firing rates. At extremely high firing rates in the present stoves, the rate of heat transfer to the bricks may not keep pace with the firing rate or the rate at which the heat is released in the combustion chamber. Therefore, the heat in the hot combustion gases, instead of being transferred to the nearest row of brick as fast as it is released, is carried farther away toward the stack. Consequently, the maximum allowable stack temperature is reached very rapidly and thereby decreases the heat stored in the stove. Clearly, if the stoves are to be fired at high firing rates to increase the heat stored in the stove, stack temperature will also have to be proportionately increased. If desired, part of the heat in these high-temperature stack gases can be recovered by heat exchange with the combustion air. The combustion air, so preheated, would help to attain the dome temperatures of 2400 F or higher that could be difficult to achieve if the Btu value of the blast furnace gas drops to 80 Btu per cu ft.

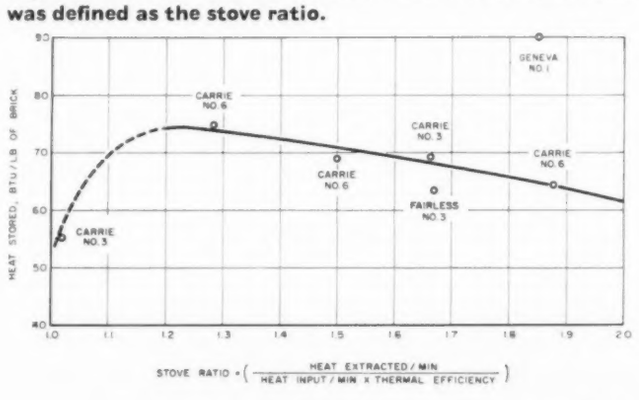
CALCULATION OF STOVE CAPACITY

By considering simple heat-balance relationships and by using the stove ratio to correlate these relationships for various stoves, within limits, the performance of existing stoves under given conditions, as well as the design features that new stoves must incorporate to achieve specified performances, can be predicted.

For example, suppose it is necessary to know whether 100,000 scfm of air can be heated from 200 to 2000 F in stoves similar to those at U. S. Steel Corp.'s South works No. 11 or 12 furnace. These stoves have 254,000 sq ft of surface per stove and are 26 ft in diameter by 123 ft high. The heat to be released at a constant rate from the stove to heat 100,000 scfm of air to 2000 F equals 3,320,000 Btu per min. If the time on blast is chosen to be 40 min, the total heat required is approximately 134,000,000 Btu. If a 3-stove system is assumed, available data indicate that the heat storage in the stove will be approximately 55 Btu per lb. Accordingly, 2,440,000 lb of brick will be needed in the on-blast stove. This is approximately equal to 248,000 sq ft of surface, since most of the bricks used in present-day stoves weigh between nine and ten lb per sq ft of surface. Thus, as a result of considering the heat storage of the stove, a 3-stove system in which each stove has 254,000 sq ft of surface would be adequate for a 40-min on-blast cycle.

The capacity of the required burners is determined by the heat-extraction rate, the stove ratio and the thermal efficiency. The heat-extraction rate and the stove ratio are already known, as explained earlier. The thermal efficiency is dependent upon the Btu value of the gas, the stack temperature, the radiation losses and the per cent of excess air. Figure 9 shows the change in the thermal efficiency with changes in the stack temperature for 92-Btu gas with variable per cent excess air and no radiation loss. Available data indicate that approximately ten per cent additional loss in thermal efficiency is suffered because of the radiation losses and the heat carried away by the excess air. Inasmuch as the design stack temperature is 800 F, the theoretical thermal efficiency will be 73 per cent at zero per cent excess air. Accordingly, the burner should be designed on the basis of 58 per cent thermal efficiency after deducting ten per cent for losses and five per cent for a safety factor. The heat-extraction rate for heating 100,000 scfm to

Figure 10 — The ratio of on-heat time to on-blast time was defined as the stove ratio.



2000 F is 3,320,000 Btu per min; therefore, 33,500 scfm of 92-Btu gas would have to be burned for 75 min to satisfy the heat requirement. The stove burner should be specified to burn at least 40,000 scfm. The 40,000-scfm burners would provide a nominal safety factor of about 20 per cent.

It should be noted that to use these high-capacity burners it will be necessary for the burner fans to develop enough pressure to overcome the pressure drop in the burner and the stove system. Recent laboratory work indicates that inadequate fan-discharge pressure can often lead to pounding in the stoves.

As an alternative to the 3-stove system for this particular problem, consider the example in which a 60-min on-blast cycle is desired. The analysis of the data indicates that for this alternative scheme, a 4-stove system would be required in which two stoves would be on blast simultaneously. Each of the stoves would have to be equipped with a 35,000-scfm burner to supply the heat in 55 min to the two stoves that are on the heating cycle.

In addition to the aforementioned considerations, a dome temperature of at least 2400 F should be specified for a 2000 F straight-line hot-blast temperature. This will provide a sufficiently large temperature difference for the transfer of heat so that the air flowing through the stove can be heated to a temperature higher than 2000 F throughout the on-blast cycle and the straight-line temperature of 2000 F can be maintained by mixing the requisite quantity of by-pass air at the mixer valve. Limited data indicate that to maintain a straight-line hot-blast temperature, the dome temperature must be at least 300 to 400 F higher than the desired constant hot-blast temperature.

Encouraged by the results obtained in the field and in the laboratory, the applied research laboratory is currently engaged in collecting and analyzing data on all stoves of the United States Steel Corp. Results of these studies will be reported at a later date.

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Discussion

PRESENTED BY

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Dr. H. W. Meyer: Jones & Laughlin Steel Corp. has developed an analog computer model of the blast furnace stove and has considerable experience in this field. It can be stated that the authors have correctly outlined the most important limitations. It is certain that checker-brick temperature and resistance of the checker brick to chemical attack represent two limitations and that stoves are presently overdesigned. On the other hand, this statement may be turned around so that the conclusion reached is that the stoves presently in existence are not being used to their maximum capacity. There is also no doubt that the firing capacity of the burner presents a limitation. It is felt that this represents one of the greatest limitations to obtaining high blast temperatures from existing stoves. Studies by Jones & Laughlin Steel Corp. have indicated that getting the heat into the checker brick without overheating the top or bottom of the stove represents something of a bottleneck. The authors are correct in stating that serious consideration will have to be given to the pressure drop across the checker mass. From a large amount of experimental data obtained on J&L's stoves, it is apparent that in certain types of checker systems high-firing rates will result in high pressure drops and, consequently, in excessive power consumption.

The basic equations proposed by the authors form a sound basis for an analog model and are essentially similar to the ones in use at J&L during the last three

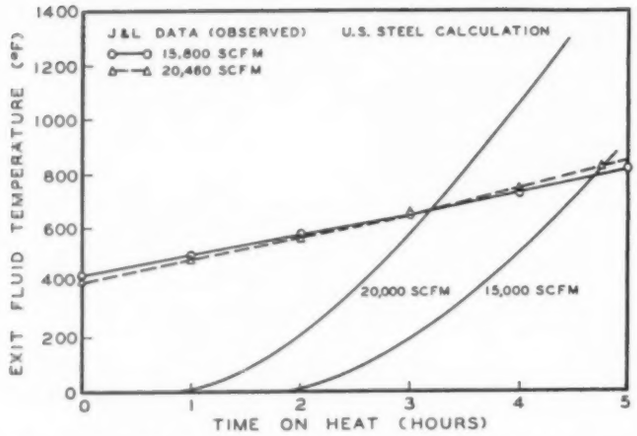

Figure 11 — Calculated curves are compared with operational data.

years. The assumptions made in order to setup the model are also reasonable. Studies confirm the fact that, after a change in operating conditions has been made, it may take a large number of cycles before a condition of cyclical stability is re-established. Also, it is not possible to get a good analog model unless a large quantity of good field data is available. Without such data, the correct relationships between the heat-transfer coefficient and flow rate, temperature, etc., cannot be established.

Some reservations arise regarding the significance of some of the figures. It is, in places, difficult to decide how the information in these figures should be interpreted. The authors suggest that Figures 3, 4 and 5 indicate how the analog can be used to study the effects of the heat-transfer coefficient and fluid flow rate on stove performance. Although Figure 3 is admitted to be an "idealized" case, it is very important to point out the difference between actual practical operating curves and these particular theoretical curves. Figure 11 shows two curves taken from the authors' data (Figure 3) with corresponding curves taken from actual operation of a blast furnace stove. It has been assumed here that the stove is 83 ft in height, i.e., the same as that used in Figures 4 and 5. The most important point to note from Figure 11 is the very large difference in slope between the theoretical curves and the practical curves. Even if the authors' curves are displaced to a starting temperature of 400 F, it is apparent that they reach a high-stack temperature faster than is observed under practical operation.

In an attempt to reconcile the differences between the calculated and observed data, several possible explanations can be put forward. The authors' data were drawn for a constant heat-transfer coefficient for all flow rates. So long as a constant heat-transfer coefficient is used, it is not possible to represent realistically the effect of fluid flow rate on the stack gas temperature. The value of the heat-transfer coefficient used is not compatible with those calculated by the authors themselves in Figure 6. One possible explanation for the difference between the value of the heat-transfer coefficient used in Figure 3 and those calculated by the authors in Figure 6 may be that the two sets of data are for stoves which are very different in size.

Figures 4 and 5 are somewhat similar in shape to the curves observed under certain operating conditions, but the value of the heat-transfer coefficient which has been chosen for these curves appears abnormally high for the flow rate considered. In addition, stoves are not normally operated during the firing cycle with a constant fluid flow rate through the stove.

In making reference to a previously published paper,[20] the authors state that the heat-transfer coefficients obtained in this work were not subject to a temperature correction. The effect of temperature variations on the heat capacity of the brick and air were taken into account in this work and it is apparent from the results that a remarkable degree of agreement can be achieved between observed and calculated stove behavior even without considering additional temperature effects. In plotting the data obtained from the reference[20] on Figures 6 and 7, it is not correct to represent these data as separate points. The data should be plotted as horizontal straight lines parallel to the temperature axis. It is presumed that the checkers mentioned as being used for Figures 6 and 7 were the same size as those used in the J&L study and that the size of the stove was also the same. Unless the checker system and stoves are identical, then the value shown for the heat-transfer coefficients measured in the J&L study cannot be compared with the calculated values. The two sets of data in Figure 6 are also comparable only if the same gas inlet temperature to the checker mass (2100 F) has been used in both cases. It is to be noted in Figure 7 that the experimentally determined coefficients lie below the theoretically calculated ones. For low flow rates, the difference between the two data would be significant. Our data extended up to a wind rate of only 70,000 scfm so that it is perhaps unwise to use these data to deduce much about flow rates in the 110,000 to 130,000-scfm region because this involves a large extrapolation. In Figure 6, two points are shown for data at 30,000 scfm. Could the authors explain the reasons for this particular representation? It may be significant to point out that the observed data for 10,000 scfm is almost exactly in agreement with the average of the values calculated by the authors for the same flow rate, see Figure 6. Although there are differences between the observed and calculated data, the fact that heat-transfer coefficients calculated from standard heat-transfer formulas are of a similar order to those experimentally determined is worthy of some note.

The authors state that they have developed an analog model which is accurate to within ten per cent of the field data. Does this mean, that they can predict the blast temperature for a given time on blast to within plus and minus ten per cent or that they can predict the time on blast for a given blast temperature to within plus and minus ten per cent? Alternatively, do the authors mean that they can predict the temperature distribution in the stove after a number of cycles to within plus and minus ten per cent? In connection with the accuracy of their model, a 7-section model has been employed. Does the model make use of higher order or simple differential equations? Experience has shown that both the type of equations and the number of sections that are chosen for the model effect the accuracy to a considerable degree.

The assertion made by the authors that the approach that they are using is a sound one is supported most

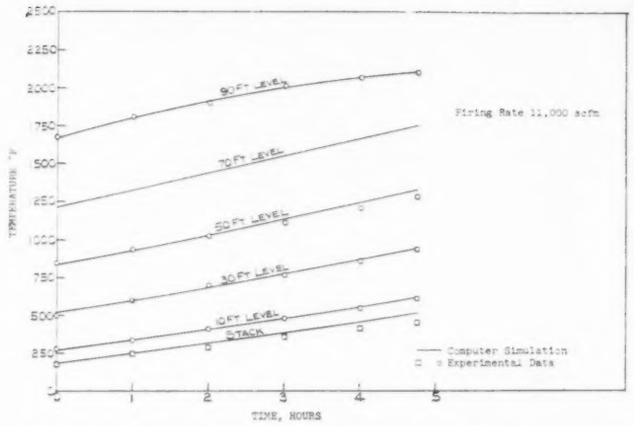

Figure 12 — Temperature transients during the heating cycle are shown.

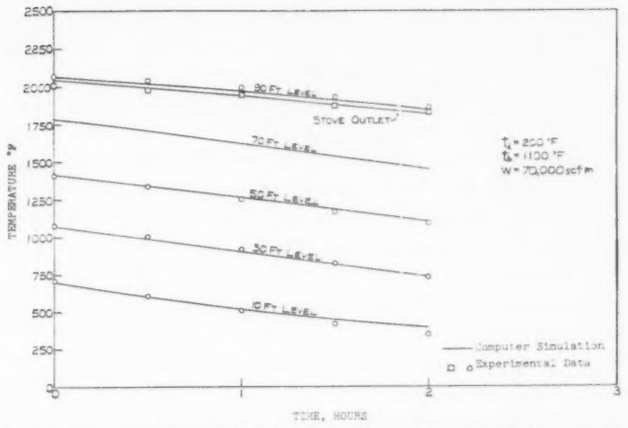

Figure 13 — Temperature transients during the blast cycle are shown.

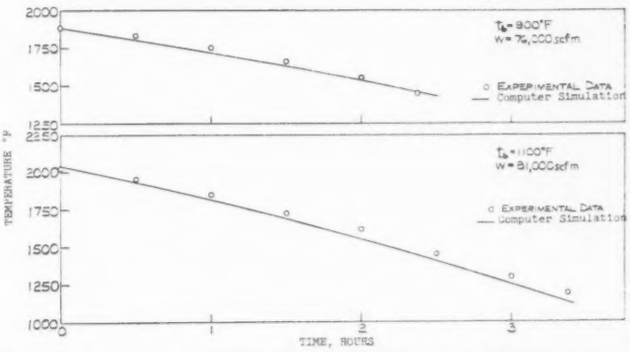

Figure 14 — General agreement was noted between calculated and observed data.

strongly by studies carried out by J&L. It is possible to use this approach, supplemented with a suitable volume of good operating data, to achieve very good agreement between the calculated and observed operation of the stove. Figures 12, 13 and 14 are taken from a paper[20] in which an approach very similar to that described by the authors was used. Equations relating the heat-transfer coefficient and mass flow rate for both the heating and cooling cycles were obtained. Once these equations were established from reference cycles, it was found that they could be used to reproduce stove operation over a range of flow rates through the stove of between 20,000 and 70,000 scfm on the cooling cycle, and between 4000 and 12,000 scfm of gas on heating cycles. Figures 12, 13 and 14 show the typical type of agreement between calculated and observed results which was obtained after the establishment of these general relationships.

E. M. Neely: Blast furnace gas, even with a 2600-F theoretical flame temperature, when burned in a stove burner would have at least 1 to ½ per cent excess oxygen due to the fluctuations in top gas analysis and this would then bring the average flame temperature to a figure somewhat under 2600 F, possibly nearer 2480 to 2500 F. As the authors point out, in order to secure straight-line temperatures of over 2000 F it becomes almost mandatory that the blast furnace gas would have to be enriched by a mixture of other fuels.

It is evident with the beneficiated materials now in use in the blast furnace, which result in the lowering of the coke rate, that the Btu content of the gas would decrease to a great extent. Some furnaces have reported blast furnace top gas of 77 Btu per cu ft. A burner of 35,000-cfm capacity with 90-Btu gas would only deliver about 90 per cent of its rating using 77 Btu per cu ft gas.

This factor offers another variable in the stove design and burner capacity and in a way leads into a vicious cycle.

Raw materials are improved, so that more stove heat can be used and coke rates can be reduced. This in turn reduces the Btu value of the gas available to burn in the stoves, which in turn requires the burning of more gas to secure the necessary Btu input. It seems that it will be necessary to supplement the blast furnace gas with higher Btu fuels or to build much larger stoves and furnish larger burners to obtain the 2000 F and over hot-blast temperatures.

D. P. Cromwell: The factual data and comments given by the authors certainly add much to the reference files for future planning and design of future stoves. They will be of considerable value in the training and educational areas, promoting investigations into the next area of "limitations" which in all probability will be from 2400 to 2800 F. Those who have operated stoves in the ranges of 1500 to 2000 F certainly have some reservations in regard to the safety of personnel when thinking that blast temperatures of 2500 F may be a common level in a few years.

There is every reason to believe that research people will develop new systems of gas burner techniques and improved heat storage and transfer methods, together with super refractories that will make the 2500-F blast temperatures possible. Many different paths are presently being pursued diligently by several laboratories in the field of gas ionization.

It is interesting to speculate a little with the figures presented. The authors relate the use of 100,000 cfm at 2000 F. Some of the new furnace designs predict the use of 150,000 cfm and 2000 F at pressures up to 50 psi. On a straight increase of 50 per cent, this furnace would require a total of 1,316,000 sq ft of heating surface.

Would the authors recommend three or four stoves?

Will the use of higher blast pressures effect the rate of heat output?

Would the authors use one or two gas burners on each stove?

Dr. M. J. Greaves: The authors' coefficient h is defined as an over-all heat-transfer coefficient. Therefore, it does not change under conditions of straight-line temperature control and constant wind; however, it is

an involved function of many factors, including:

1. Brick temperature, which is a function of time and two or more linear dimensions.
2. Gas temperature, which is a function of time and at least one linear dimension.
3. Surface conditions, which are subject to change with age and use of the stove.
4. Shape and arrangement of checkers which are different for each designer and builder of stoves.
5. Density, viscosity, conductivity, specific heat and composition of air including in particular CO_2 and water vapor.

An approach that takes all of these factors into account is quite cumbersome, but the neglect of any of these items would contribute to inaccuracy in the results.

The disadvantage of using an analog computer is that, while it is relatively easy to simulate a limited number of conditions, it is impractical to include enough factors to find an accurate solution to the general case. The use of existing stoves for obtaining design and operating data is a common application of analog computer techniques. In such an application, the stove serves as the computer and all that is required is the necessary instrumentation to obtain the desired data.

Most of the stoves designed by our company are based on empirical data which have been collected over a period of 50 years and which we believe to be more than 95 per cent accurate. The technique referred to is not particularly effective for stoves designed by others.

The required brick mass per stove is calculated by the following formula:

$$M = \frac{V \times t_b \times D}{C \times T_m}$$

where:

M = Mass of brick, lb
V = Volume of blast, cfm (standard conditions)
t_b = Length of air heating period, min
D = Increase in sensible heat of air, Btu per cu ft
C = Average specific heat of brick, Btu per lb, F
T_m = Logarithmic mean temperature drop of brick, F

To calculate T_m, the temperature of the dome brick at the end of the blast cycle must first be determined. This temperature varies with the temperature of the hot blast and the heat transfer rate of the stove as determined by actual tests, is shown in the heat transfer rate curve, Figure 15. The heat transfer rate of the stove is determined by the following equation:

$$\frac{V \times D}{A}$$

V and D are as previously defined and A is the heating surface per stove in sq ft. A heating surface per stove is assumed from experience, but it must agree with the heating surface finally selected.

From the heat-transfer rate of the stove, the terminal-approach temperature is obtained from Figure 15, and by adding the terminal-approach temperature to the hot-blast temperature, the temperature of the dome brick at the end of the blast cycle is obtained. The following example illustrates the necessary steps:

Required: A stove to hold 1800-F hot blast for one hr with a blast volume of 100,000 scfm.

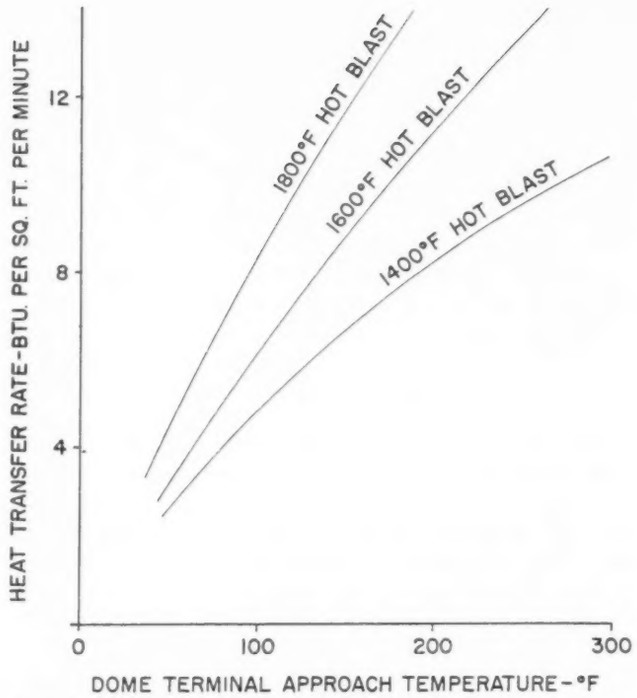

Figure 15 — The dome-brick temperature at the end of the blast cycle is obtained by using data from the chart shown.

Given: Maximum dome temperature = 2200 F; Maximum stack temperature = 600 F; Cold blast temperature = 200 F.

Based on experience, a brick mass of 2,200,000 lb per stove is first assumed. The corresponding heating surface is 230,000 sq ft.

The heat transfer rate will be:

$$\frac{V \times D}{A} = \frac{100{,}000(33.5 - 2.5)}{230{,}000} =$$

13.5 Btu per sq ft per min

From Figure 15 the minimum temperature of the dome brick is 175 F above the temperature of the hot blast.

Check the assumed brick mass M:

$$\frac{V \times t_b \times D}{C \times T_m} = \frac{100{,}000 \times 60(33.5 - 2.5)}{0.282 \times 304} =$$

2,170,000 lb

This figure agrees closely with the assumed value.

Three 26 x 114-ft stoves would be used each with 2,200,000 lb of checker brick. While this procedure is not a general solution, it is quite satisfactory for routine stove design.

Also, there is another solution to the design of a stove which takes into account some 50 or 60 parameters known to effect stove design. This solution is based on the theory proposed by Dr. Schack.[21] The solution is facilitated by means of a digital computer which can solve a typical stove problem in about six hr. This program is being adapted for use on a large computer in order to reduce the computation time. The advantage of this solution is that it is fairly general and can be applied to any of the conventional stove designs.

The basic equations for this solution may be of interest and follows the table (Table II) giving the nomenclature used.

Flue gas volume:

$$W_s = W_f R \frac{t_b}{t_h}$$

Convection, heat-transfer coefficient:

$$d = \frac{4a}{B} \qquad S_b = \frac{W_b}{3600A_1} \qquad S_s = \frac{W_s}{3600A_1}$$

Blast:

$$h_c' = \frac{7.5(S_b)^{1/2}}{d^{1/3}}$$

Gas:

$$h_c = \frac{7.5(S_s)^{1/2}}{d^{1/3}}$$

Convection and radiation:

$$h = h_c + h_{sm}$$
$$h_1 = h + h_{sm}$$

Theoretical heat transfer:

$$H_2 = \frac{1}{1/ht_h + 1/h_c't_b}$$

$$H_1 = \frac{1}{1/h_ct_h + 1/h_c't_b}$$

Brick efficiency:

$$n_B = f\left(\frac{4y(t_h + t_b)}{s^2cp}\right)$$

Water equivalent:

Blast: $E_b = W_bt_bc_a$
Gas: $E_s = 0.96W_st_hc_g$
Ratio: $\frac{E_s}{E_b}$

Efficiency of heating surface:

$$x = \frac{(h + h_c')(t_h + t_b)}{2\,csp}$$

$$u = \frac{1}{x}(1 - e^{-x}) + 9.52\,y\left(1.05\left[1 - \frac{1}{x}(1 - e^{-x})\right] - \frac{1.05 - 1/x\,(1 - e^{-x})}{1 + (0.1/x)}\right)$$

$$v = 1 - \frac{x}{2}\left(\frac{1}{x}(1 - e^{-x}) - \left[\frac{1}{x}(1 - e^{-x})\left(\frac{1 - n_B}{n_B}\right)\left(1 + \frac{2}{(8/x) - 1}\right)\right] + \left(\frac{1 - n_B}{4n_B}\right)\left(1 + \frac{1}{8/x - 1}\right)\right)$$

$$n_H = \frac{u}{v}$$

True heat transfer:

$$H = H_2n_H$$

If θ_b' is given, calculate A:

$$f = \frac{\theta_s - \theta_b'}{\theta_s - \theta_b}$$

$$A = \frac{E_s}{H[1 - (E_s/E_b)]}\left(\ln \frac{1}{\{1 - [1 - (E_s/E_b)]/f\}\frac{E_b}{E_s}}\right)$$

If A is given, calculate θ_b':

$$f = \frac{1 - (E_s/E_b)}{1 - (E_s/E_b)e^{-\{HA/E_s[1-(E_s/E_b)]\}}}$$

$$\theta_b' = \theta_s - (\theta_s - \theta_b)f$$

Mean stack gas temperature:

$$\theta_s' = \theta_s - (\theta_s - \theta_b)E_b/E_s(1 - f)$$

Stove efficiency:

$$n_{st} = \frac{E_b}{E_s}(1 - f)$$

Hot-blast temperature drop:

$$\theta_2 = \frac{2H(\theta_s - \theta_b')}{cspn_B\left(1 + \frac{W_sc_s}{h_c'A} \times \frac{HA/E_s[1 - (E_s/E_b)]}{1 - e^{-\{HA/E_s[1-(E_s/E_b)]\}}}\right)}$$

Stack gas temperature increase:

$$\theta_1 = \frac{\left(\frac{n_H}{cspn_B}\right)2H_1(\theta_s - \theta_b')e^{-\{HA/E_s[1-(E_s/E_b)]\}}}{1 + \frac{W_sc_g}{h_cA} \times \frac{\left(\frac{HA}{E_s}\right)\left[1 - \left(\frac{E_s}{E_b}\right)\right]e^{-\{HA/E_s[1-(E_s/E_b)]\}}}{1 - e^{-\{HA/E_s[1-(E_s/E_b)]\}}}}$$

Check y with θ assumed to be zero:

$$y = \frac{\theta + \theta_2}{\theta_s - \theta_b'}$$

Dome temperature:

$$T_s = \frac{h_1t_h\theta_s + h_c't_b\theta_b'}{h_1t_h + h_c't_b}$$

$$T_d = \frac{0.8H(\theta_s - \theta_b')}{csp}$$

Certainly important is the obvious possibility of improved over-all performance by preheating combustion air in an auxiliary heat exchanger or a stove which has been on blast but cooled to the point where it will no longer heat all the air to the desired temperature.

T. R. Schuerger and Dr. J. C. Agarwal: Figure 3 shows stove exit-gas temperature plotted as a function of time for a single heating cycle and for several different flow rates. These data do not represent a condition of cyclical stability, so the comparison in Dr. Meyer's Figure 11 is not valid. Dr. Meyer's data are for exit-gas temperature for a cyclical operating condition. The data shown in Figure 3 represent a condition not achieved during actual stove operation. The purpose in presenting the figure is to indicate the general effect that mass flow rate has on stove heating rate and stack-gas temperature.

The selection of heat-transfer coefficients for the studies shown in Figures 3, 4 and 5 was somewhat arbitrary since there was no attempt to reproduce actual operating conditions. Rather, it was an attempt to learn something of the more general nature of the stove. It is too early in the studies to predict the actual effect of variable vs constant heat-transfer coefficients on analog performance.

It is realized that the heat-transfer coefficients taken

from Dr. Meyer's earlier paper should be plotted as straight lines horizontal to the temperature axis. The points shown in Figures 6 and 7 represent the intersection of the straight lines with calculated curves. The point in Figure 6 that appears to have gone astray belongs off to the right on the indicated ordinate on the 30,000-scfm wind-rate line.

An absolute accuracy is extremely difficult to establish for an analytical program of the present form. The ten per cent accuracy that was mentioned refers to the accuracy with which we were able to reproduce measured brick temperatures when operating the analog at measured firing rates and times and measured blast rates, temperatures and times. These criteria are for the conditions of both stove and analog cyclical stability.

The analog-computer program was thoroughly tested in its early stage of development to find its sensitivity to the number of sections that are used. With simple second-order difference formulas little variation could be observed among 6, 8 and 10-section programs.

Concerning the lowered Btu content of the blast furnace gas on the burner firing rate because of the decreasing coke rate, it is strongly recommended that the burners be fired not on volume of the blast furnace gas burned but on the Btu released per min. If the Btu value of the gas drops to below 80 Btu per cu ft, it may be necessary to enrich the blast furnace gas in order to achieve a high blast temperature (2000 F) otherwise the attainable dome temperature may be too low.

On stoves for 150,000 scfm of 50-psig air, to be heated to 2000 F, it is recommended that:

1. Three stoves instead of four be used, primarily because it is more expensive to build four stoves than three even though both stove systems would contain the same number of sq ft of checker surface.

2. The use of higher blast pressure may affect the rate of heat output because of its effect on the Reynolds number, and as a result the heat-transfer coefficient. However, at present no comment on the extent of the effect of high pressure can be made.

3. The use of one or two burners on the stove would depend on the design of the particular burner. Naturally, unless there is an obvious advantage in having two burners instead of one big one, there is no point in having multiple burners.

Dr. Greaves' discussion of the variability of the heat-transfer coefficient h is sound, and this variability must be properly considered if valid computer results are to be obtained. One of the problems is that the exact effects of using average constant heat-transfer coefficients are not known. In the present article some of the early work with the use of an analog computer for simulating the cyclical operation of a stove has been shown. One of the areas still being studied is the effect of variable thermal properties (specific heats and heat-transfer coefficients) on the computational program.

The present analog-computer work is not to be considered the terminal point in the studies. Present interest deals with dynamic studies of the regenerator system. Perhaps the work will lead to a new computational approach for designing stoves, but if this point is reached the present mathematics will be programmed for digital computation. As Dr. Greaves has mentioned, the analog program is being used as a simulator; it is felt that this approach offers a great deal more flexibility than field work alone can supply.

Dr. Greaves has presented interesting methods for designing stoves. The first method is a method of determining the heat storage in the stove by the log mean temperature drop of the bricks. The empirical relationship shown in Figure 15 provides an adequate approximation of the brick-temperature drop for the dome end of the checker system for hot-blast temperatures up to 1800 F. However, for the stack end of the checkers, the brick-temperature drop seems to have been based on the difference in the temperature of the stack gases and the incoming cold blast. This procedure will have a tendency to give a higher log mean temperature drop of the brick. However, the procedure is simple and straightforward and should give reasonable answers.

Dr. Greaves' presentation of the equations used for calculating stove design with a computer is also of interest. It is felt that these have been of great help in designing the stoves properly.

It would be of interest to learn how well the approximate stove calculations and the calculations based on Dr. Schack's theory check with measured operating data. It is well to emphasize again that the calculations Dr. Greaves describes have a limited use in the study of dynamic or transient behavior of stoves.

In conclusion, to properly understand the problems of design and operation of the stoves, a considerable amount of data on already existing stoves is needed. It is hoped that everyone concerned will cooperate in making the information available, for the sake of a better understanding of the problem of the limitations of blast furnace stoves.

The limitations of the stove can be divided into two groups, one governed by physical considerations and the other by process consideration. Among the limitations governed by physical considerations are:

1. The height and the diameter of the stoves are limited by structural considerations.

2. The number of stoves in a stove system cannot be less than two because one stove is always on blast and the other is on heat. Also, there should not be more than four because of the cost of building a large number of stoves.

3. The maximum dome temperature is limited by the available refractory materials.

4. The maximum stack temperature is limited by the strength of the material supporting the checker work at high temperatures.

Among the limitations governed by the process considerations are:

1. Time cycle on blast should be shortened consistently with automatic or manual stove changing. Shorter on-blast cycle leads to higher blast temperatures.

2. The calorific value of the top gas burned should not be lower than 85 Btu per cu ft to obtain sufficiently high temperature in the combustion chamber, and high heat release per cu ft of gas burned.

3. The stove burners should be designed for an adequate burning rate consistent with heat requirement and over-all thermal efficiency.

4. The burner fan should provide enough air at sufficient pressure to overcome the pressure drop in the stove system.

5. Proper insulation of the hot-blast main should be provided to minimize the drop in the hot-blast temperature caused by heat losses from the hot-blast main and the bustle pipe. ▲

INTEGRATED AUTOMATION for Steel Plants

by W. M. KRUMMEL, Metal Rolling and Processing Engineering,
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. . . section by section automation of a plant can increase its operating economy and produce important intangible returns. Extensive study and careful estimating of expected savings are necessary before any automation decision can be reached . . . .

THE term "integrated automation" expresses a concept which for years to come will dominate the thinking and actions of those responsible for shaping the future of the steel industry.

As with the older terms mechanization and electrification, integrated automation represents an opportunity for the steel industry to attain increased productivity, increased quality, reduced operating costs and improved utilization of process facilities. Moreover, integrated automation represents a new manufacturing system which will be much more responsive to management control than existing systems.

DEFINITION

The definition is: "Step-by-step automation of separate processes, each as self-sufficient as possible, and integrated into an over-all automation system, based on the needs of the business, whether large or small."

A short discussion of the terms automation and integrated may serve to expand the technical meaning of the definition:

Automation—Automatic production of actual products and of associated business data, decisions and reports. Examples of steel mill activities affected by process automation are operations and engineering. Examples of activities affected by business automation are production planning, accounting and marketing.

Integrated—The above activities could be automated individually; however, they are closely interrelated by common data requirements. Integration represents the combination of some or all of these activities into a composite system in the interests of economy, efficiency and relative simplicity.

ULTIMATE AUTOMATION

The concept of ultimate mill automation extends well beyond the scope of equipment and system design that the industry could be expected to purchase immediately. However, the interests of the steel plant are served best by studying the plant in terms of ultimate total automation insofar as possible, and then by proposing a logical step-by-step approach to attaining the ultimate.

Each step proposed must itself be capable of producing real benefits, and must continue to produce these benefits after the implementation of subsequent steps. Each step likewise should consist of small-to-moderate size building blocks.

Ultimate automation of a typical mill area would include all or some of the following automated functions:

1. Completely automatic operation of all rolling and processing units, including setup adjustments, threading or starting, running, shutdown and emergency corrective actions.
2. Completely automatic flow of products through the area.
3. Ordering and expediting of finished and semi-finished products, raw materials, supplies and spare parts.
4. Packing, labeling, warehousing and shipping of finished products.
5. Maintenance of inventory levels of raw materials, steel in process, finished products.
6. Order service activities and communications with sales offices.
7. Production planning, including forecasting of labor and processing unit utilization and planning of maintenance schedules.
8. Payroll, cost and general accounting.
9. Production, financial, customer service, maintenance and general management reporting.

In order to be realistic and economically justifiable, integrated automation for a particular steel plant must be based on the business and operating "facts of life" facing the individual steel plant and steel company.

The systems know-how, equipment and manpower to attain integrated automation are available now. The incentive for the steel company is there in terms of both immediate profit and protection of future business position. It will be attempted to indicate in this article the feasibility of and benefits to be attained from integrated automation.

THE PRIMARY ROLLING MILLS

In considering the step-by-step plan for integrated automation the terms "islands of automation" and "areas of automation" are used. These terms reflect the arrangement of the steelmaking process. There are many processing units in the steel plant whose functioning can be more or less separated from the unit processes both downstream and upstream by product storage areas. For instance, consider the primary rolling mills, see Figure 1. It is easy to pick out the separate units: the soaking pit, slabbing mill unit; and the hot strip mill unit with its reheat furnace, roughing mill and finishing trains. Each of these units will be called an island thereby indicating that its automation can be made relatively self-sufficient.

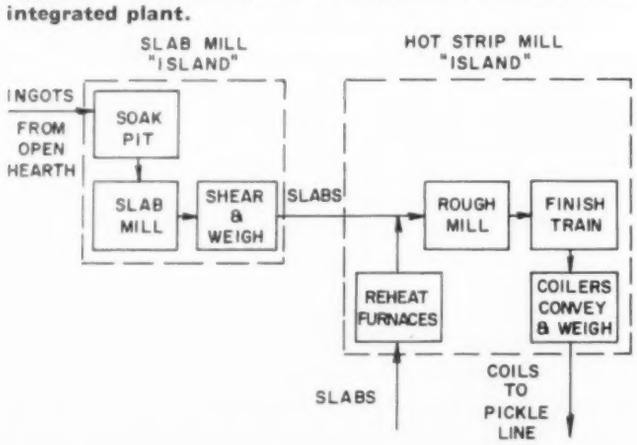
The next step toward complete automation is the linking of the several islands in the process flow into an automated area. For this example the primary rolling mill area is used. Upstream from this area is the open hearth area and downstream the cold mill area.

Hot strip mill island—Associated with each automated island is a process control system, see Figure 2. This system has two basic functions: a mill operating control function and also an automatic mill scheduling, order tracking and data acquisition function.

The mill operating control function performs many of the routine decision, memory and action functions of the human operator. In the block diagram representation, this function is shown as sharing space with the human operator, thereby indicating that for some installations it may still be desirable to have the operator share operating functions with the computer. For another, the operator's functions would be a minimum. The arrangement is flexible and depends upon the particular circumstances of the application.

The order and data function not only gathers process

Figure 1 — Automation can be applied to sectors of an integrated plant.



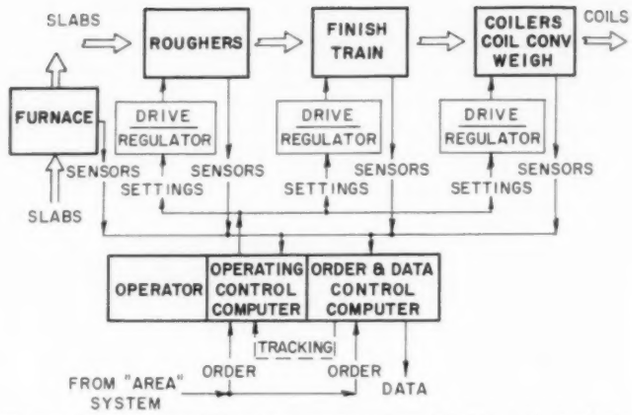


Figure 2 — Control for the process involved in the individual sectors can include scheduling, data compilation, etc., in addition to mill operating control.

information such as temperature, rolling times, gage and width, but correlates this information on a per slab, per coil, per order and per turn basis. This correlation can be considered as actually a tracking function. Slabs are tracked as they are pushed through the reheat furnaces. The identifying code for each slab is stored in the memory as the slab is charged into the furnace. Further charging and discharging operations are confirmed to the computer by means of hot metal detectors, relay and limit switch closures, or by the furnace operators. The computer tracks the slabs as they come out of the furnace and progress through the mills. At points along the process, sensors feed the computer information such as footage of on-gage, off-gage, on-width, off-width, charge weight and coil weight, total coil length, rolling times and temperatures. This information is converted into computer language and stored in the memory, each piece of information being assigned to the proper slab or coil within the memory system.

The mill order and data control function can be related directly to automatic operation of the mill because of the tracking function. Since the order system memory will know what slab is in any specific location at a specified time, it can display to an operator the information required to set up the mill for the first slab of the next order. One step further, the order system can automatically communicate to the mill control computer, at the correct time, the coded information that initiates computer operation necessary to correctly setup the mills for the next order. This is the meaning of the dotted tracking line tying together the two basic functions.

The island process control system can be arranged to communicate directly with an area-process control system as will be shown later.

The mill control computer can be described as an optimizing system. The inputs to a system for the hot strip mill island essentially consist of the incoming slab thickness, width and temperature. These may be automatic inputs received from sensors. In addition, the grade of steel and desired delivery gage and speed are required inputs. These can be inserted manually by the operator or can be communicated directly from the order function as part of the tracking described above. The control computer, upon receiving the inputs, will calculate the required rolling instructions in accordance with a program stored in its memory. The instructions

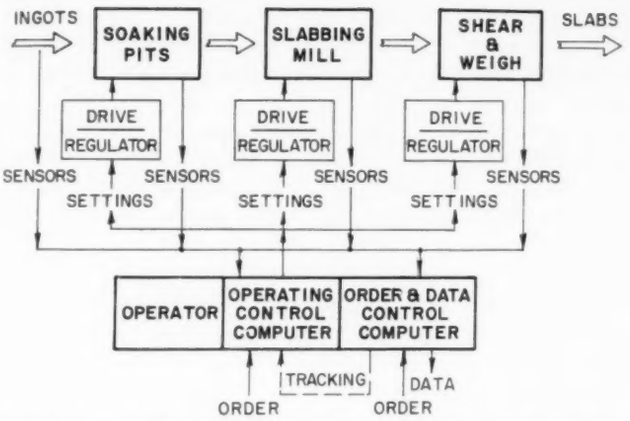


Figure 3 — Each sector will be automated in the same general pattern so that feedback relationships can be established.

will be settings for speeds, screws, guides and gages for the roughing mill and for the finishing mill, which will be fed automatically into the appropriate regulating controls. The computer will then observe through sensors the operating results and compare these results with the original requirements. The mathematical relationships stored in its memory will be updated and revised rolling instructions for the next slab will be computed.

There are other inputs that would be required such as adjustment of the last stand to produce a constant draft in order to control shape. Also stored within the computer memory are limits of operation, such as: electrical drive rated limit, maximum roll separating force and minimum and maximum delivery speeds.

Soaking pit-slabbing mill island—The island of the soaking pits and in-line slabber would be automated in the same general manner as the hot strip mill, see Figure 3.

The mill order and data control system provides the tracking function, storing within its memory ingot identification and location in the soaking pits and accumulating information on the ingot heating and soaking history. When the ingot is withdrawn from a pit, moved to the approach table of the slabber and rolled through the slabber, sensors inform the order system of slab progress so that individual slab position is tracked in the computer memory. At the shear the number of pieces sheared is noted and identification codes assigned in sequence to each piece of the original slab.

The order function for this island could have several communication ties with important auxiliary drives. For instance it can provide the basis for more automatic operation of the soaking pit area.

The order system has stored within its memory the conditions existing in the entire soaking pit area: ingot location, pit locations available for fresh ingots and ingots designated as ready to be rolled. A program can be stored in the system memory to provide optimum loading and unloading, firing and soaking cycles for the pits. The soaking pit crane would become a position regulated auxiliary, moving into position for loading and unloading in accordance with co-ordinate position settings furnished by the computer. Instructions can be either displayed to the crane operator or communicated directly to an automatic crane control and position regulator. Soaking pit covers open and close automatically as required. The ingot buggy can be brought to the required position automatically.

The mill operating control function performs for the slab mill in much the same manner as for the finishing mill. It can be an optimizing computer, calculating for each pass the required draft, main and edger roll openings, roll speeds and guide settings in accordance with power curves stored in the computer memory. The computer compares the results of rolling for one pass using roll separating force, shaft torque and other sensors. It then will make necessary adjustments in its

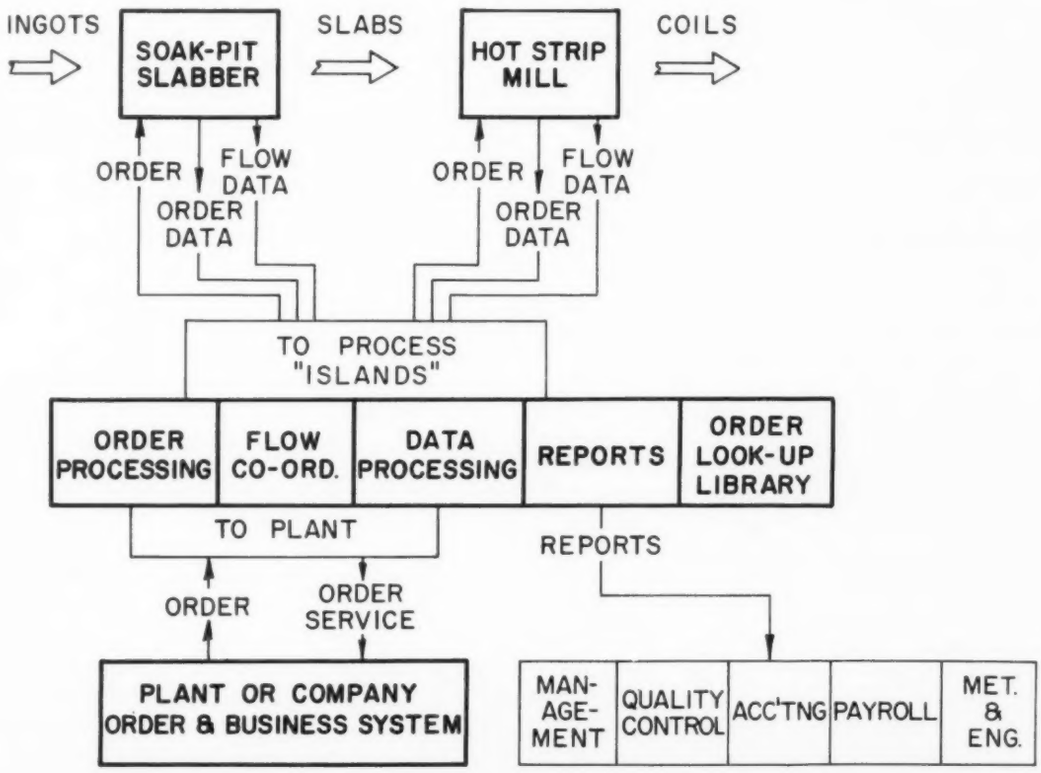


Figure 4 — Communications with the order and accounting offices and process scheduling can be controlled from a control area.

calculation to obtain optimum mill settings for the next and subsequent passes. Results of calculations are compared against limits such as electrical torque, roll separating force and draft.

AREA AUTOMATION

The islands can now be bridged through the area automation equipment, see Figure 4. It is also at the area level that it is most desirable to have the process automation system communicate with the plant business automation system as in Figure 4.

An area process control system would perform the functions of:

1. Processing incoming order information for the area, received from the plant or company-wide order system.
2. Preparation of area order schedules in the form of either typed instructions for operators or coded instructions to be communicated directly to the island automation systems.
3. Co-ordination of product flow between islands.
4. Processing of data feed-back from the islands in the area.
5. Memory file of all in-process orders in the area and their island locations.
6. Reassignment and rescheduling of orders within the area based upon cobble, reject or shortage information fed back from any of the islands.
7. Storage, in a "look-up library" function, of auxiliary order information not actually needed for producing the product in this area, but needed for processing in other areas or for the producing of complete reports.
8. Preparation of reports to various departments and to general management on operations within the area.

The equipment necessary to perform these functions and to provide direct communication between process computers and business computers is available. There will be a wide range of levels of communication among different types of computers and different islands and areas. Traditionally the transmittal of information has been accomplished by means of handwritten or typed schedule sheets, which have been passed back and forth between the operating units and the accounting, order scheduling and order service units. Recently there has been some use of punched cards. In some cases it will be entirely feasible to have the area systems wired directly into each of the island systems and into the company-wide order system. In other cases communication will be best served with magnetic or paper tapes or punched cards. The conventional typewritten order schedule sheets would probably be continued in use for some time, first as a communication link and then later as a check on the satisfactory operation of the automation equipment. The needs of the business, together with the economics involved, determine the choice of system and equipment.

EQUIPMENT INVESTMENT JUSTIFICATIONS

Equipment purchases in the steel industry in most cases must be justified in terms of a suitable return upon the investment.

It is difficult to estimate the full value of the return upon the investment in automation equipment. The return will consist not only of tangible dollar savings in terms of reduced cost, reduced inventory levels, improved product quality and decreased maintenance, but also, and perhaps more significantly, the return will consist of such intangibles as increased management control over the enterprise, improved market position, improved accounting and order systems, accurate and complete records and better customer service.

The estimating of future dollar savings requires knowledge and effort. Intimate knowledge of plant operations and costing systems coupled with a thorough understanding of the proposed integrated automation scheme for the particular steel plant is required.

The feasibility study approach has been used to aid in the solution of this problem. Where this approach is chosen a joint task force of steel company and electrical supplier representatives can study the proposed project for a selected steel plant. Specific proposals in terms of step-by-step application of automation systems can be worked out. The effects on the plant's operating economy can then be evaluated in terms of dollar return on the investment. Intangible returns which may be as important as the dollar savings can also be documented. The results of this approach can enable management to justify a plan to place automation effort in those areas where the need and expected return are greatest.

In some instances sufficient experience is already available as the result of making studies and automating similar processes. This permits plans to be made and action to be taken on a more immediate basis.

ANTICIPATED BENEFITS

Some of the anticipated benefits that might be expected from integrated automation have been mentioned in general terms. A few of these areas of cost and quality improvement for the primary rolling mill area example should be examined in more detail:

Increased mill utilization—A characteristic of an automation system is its impersonality. In the hot strip mill island for instance, the computer replaces the individual operator's "little black book" of roll, screw and speed settings for the various rolling schedules. Operators vary in their methods of operating the mill. An evaluation study conducted for one mill showed that production rates for the first and third turns were considerably below that of the second turn. The control computer would tend to equalize production not at the average but at the highest manual operator level, in this case the second turn. The saving was estimated in terms of a reduction in operating time of 500 hr per year for a yearly production of 1,500,000 tons. The rolling rate of a mill is not dependent solely upon the power rating but also upon the capacities of furnaces, coilers and other auxiliaries and upon operator efficiency. An automation system, using the order tracking function tied into the input of the control computer, would reduce mill delays due to setup time, would practically eliminate mistakes in setup and would reduce delays due to cobbles, check sheet errors, check board delays, cold steel and the like. For the aforementioned mill under study, the saving in mill delays was estimated in terms of a reduction in operating time of 200 hr per year.

Lower operating costs—Much roll and equipment damage is caused by operator setup mistakes. Monitoring functions are included in the control computer system to protect against improper setup, to provide for instance, for the optimum mill warm-up operation after roll changes. As another example, fuel costs represent an expensive item in the steel plant operating budget. These costs can be reduced in the soaking pits by means of computer-controlled ingot loading and unloading, and computer-controlled firing rates and soaking times. Fuel costs can be reduced in the reheat furnaces by adjustment of firing zone controls to compensate for slab pushing rates. It has been estimated that fuel savings can exceed $50,000 per year for the reheat furnaces alone with a 1,500,000-ton yearly production rate.

Accurate records and punctual instructions—Consider the many times that instructions and mill data are manually entered, re-entered and manipulated by operators, clerks, typists, key punch operators and messengers. Each handling represents a new opportunity for introducing erroneous readings and recordings. Each handling represents an additional time delay in obtaining process data vital to the operation of the mill. Data concerning mill output is normally not available until after a turn has been completed. It then must be processed through the mill office, retyped or rewritten and hand carried to other data processing centers before a report can be made available for order scheduling or management.

Integrated automation represents machine-processed instructions to other computers or to operators. Accurate reports are made upon demand or on a regular schedule. Mill schedules can be changed almost instantaneously, if required, by the occurrence of cobbles, rejects or product diversions. Information such as coil weights can be handled entirely by the automation system from the coil scale weight sensor to the final report.

One interesting aspect of the value of keeping accurate and complete records is the facility in answering customer complaints on past orders. Upon receipt of a complaint, a quick check produces the complete order history: metallurgy, gage, width and tolerances.

Management control—This has been mentioned frequently. How many dollars can be credited to management being able to obtain accurate timely information on mill performance so that decisions can be made and executed in time to be effective? Consider the advantages of furnishing general management with machine-made reports direct from the process untouched by the four or five layers of clerical operations, foremen and supervisors, that presently shield general management from production information.

SUMMARY

Integrated automation is a practical concept which has been occupying the working hours of many of us this year and certainly many more of us in the years to come. Integrated automation is practical and economical when taken a step at a time, within the framework of a well developed plan for the automation of the entire steel plant. In this article one area where there is presently considerable activity along the lines indicated was taken as an example. Other areas such as the tin mill area and hot metal area are as active, and within the next year or so one is likely to see a number of island systems and several area systems in design or operation.

An interesting sidelight on this activity is the type of thinking now required of the steel plant engineer. He must now be concerned with systems that involve not only electrical and mechanical machinery and computer equipment, but involve parts of the steel plant operation in which he probably had taken less than a passing interest before. The steel plant engineer must now consider working with systems and procedures for order scheduling and cost control. He must have knowledge of his company's business systems, and his work involves business engineering as well as electrical engineering in applying integrated automation to his company's operations. ▲

Revised and rearranged collection of articles which appeared in the Iron and Steel Engineer between 1943 and 1950 . . . a book for rolling mill men and for anyone interested in rolling mills and roll design . . . written from a practical viewpoint by one who has had considerable experience in the art of roll design.

ROLL DESIGN and MILL LAYOUT

by **ROSS E. BEYNON**

Price: To AISE Members . . . $3.00
To Others $5.00

ASSOCIATION OF IRON AND STEEL ENGINEERS

1010 Empire Building **Pittsburgh 22, Pa.**

1961 AISE ANNUAL CONVENTION—

◀ Typical of attendance at the technical sessions was this turnout for I. G. Orellana's paper, "Recent Developments In Strip Thickness Control."

▼ G. T. Collatz and J. D. Kinsey, Cleveland Worm & Gear, chat with T. B. Ryan, Stilwell Co.

▲ C. H. Vaughan presides at the Joint IHEA and AISE Session on Continuous Furnace Processing.

▼ Elmer Barthel, Pittsburgh Steel, and R. C. Foster, Allegheny Ludlum, take a break between sessions.

▼ Ned Steele, Harbison-Walker Refractories Co., and Paul Stock, Bussmann Manufacturing Division, McGraw-Edison Co., catch up on convention doings via the Daily News.

PICTORIAL REVIEW

PENN-SHERATON HOTEL • PITTSBURGH, PA.

SEPTEMBER 25, 26, 27, 28

▲ W. T. Hogan, S. J. (left) presents his paper, "Capital Investment and Productivity Measurement." E. B. Speer (right) speaks on "The Changing Open Hearth."

▲ Pittsburgh's Golden Triangle forms the backdrop for these AISE ladies enjoying brunch at the LeMont.

▼ W. E. Boger, Vice President, Operations, Alan Wood Steel Co., T. J. Ess, Managing Director, AISE, and H. L. Jenter, Vice President, Operations, American Steel & Wire Division, U. S. Steel Corp., engage in some small talk.

▼ Reception for the Speaker's Table guests brought together this group of AISE past presidents.

▲ C. E. Pritchard, AISE president chats with C. H. Williams, Administrative Vice President, Engineering, U. S. Steel Corp., and Frank B. Rackley, Chairman of the Board and President, Jessop Steel Co.

▼ This is a portion of the 839 persons attending the formal banquet.

1960 AISE Papers Award Won By J. S. Ride

THE 1960 Kelly Award winners were named at the 1961 AISE annual banquet on September 27 at Pittsburgh, Pa. First place was awarded to John S. Ride for his paper, "Analysis of Operational Factors Derived from Hot Strip Mill Tests." Mr. Ride is now associated with the E-A Automation Systems Limited, Century works, Lewisham, London SE 13, England, but at the time he wrote the paper he was metallurgist, development and special duties div., metallurgical dept., The Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada.

The paper was published in the November, 1960 *Iron and Steel Engineer* and describes research and tests on operating mills which are essential for successful application of automatic equipment. This is a report of the pioneer work in this field carried out at Stelco.

The second place winner, "Blowing Methods in Steelmaking," by G. Yocom, assistant to general manager, and L. Xidis, chief metallurgical engineer, bessemer, Steubenville works, Wheeling Steel Corp., Steubenville, Ohio, was published in the September, 1960 *Iron and Steel Engineer*. This paper tells how the production of tonnage oxygen at low cost has stimulated interest in pneumatic processes, has made possible large strides in vessel size, amounts of permissible scrap addition and grades of steel which can be produced. A new method developed by the authors which was being installed at Wheeling Steel was also described.

First place winner J. S. Ride, second from left, shares the spotlight with fellow award winners. Left is L. E. Ringger, who with G. S. Koss, won third place. Next to Mr. Ride are second place winners, G. Yocom and L. Xidis.

G. S. Koss, assistant division superintendent—rolling mills, and L. E. Ringger, assistant to general superintendent, Geneva works, Columbia-Geneva Steel Div., United States Steel Corp., Provo, Utah, won third place for their paper, "Application of Speed Regulators to the Geneva Works Hot Strip Finishing Mills." In this paper which appeared in the January, 1960 *Iron and Steel Engineer*, the authors show that the true importance of speed regulators is that they represent a step toward a mill which can correct product dimension variations and deliver a better product. The authors also received honorable mention for another paper on the same general subject entitled, "Automatic Thickness Control—Geneva Works Hot Strip Mill," which was published in the *Iron and Steel Engineer*, February, 1960.

Herman Muller also received a honorable mention for his paper, "Applications of Roll Ragging," which was published in the *Iron and Steel Engineer*, May, 1960.

The Kelly award carries prizes of $300, $200 and $100 for the first, second and third place respectively. The award was established in 1943 to honor John F. Kelly, managing director of the AISE from 1917 to 1934, and to perpetuate the memory of his achievements in the advancement of the Association.

The award is made each year by the board of directors of AISE upon the recommendation of the editorial and executive committees of the AISE. Rules of the award:

1. The award shall be given annually to the author of the best paper adjudged of greatest value in the advancement of engineering or operating practice in the iron and steel industry.

2. The entries for each judging shall be the papers published in the *Iron and Steel Engineer* during each calendar year, although some may have been presented at meetings in the previous year.

Voluntary contributions of papers not presented at meetings but published by the AISE are also included in the judging.

3. To be eligible for the award, the author must be directly employed in the iron and steel producing industry. The author need not be a member of the Association of Iron and Steel Engineers.

4. The award shall be made at the annual fall meeting following the close of the calendar year.

5. The award shall be made by the board of directors of the AISE on the recommendation of the executive committee of the AISE. ▲

Solutions To Basic L-D Plant Layout Problems

by J. W. IRVIN, Senior Project Engineer,
Kaiser Engineers, Div. of Henry J. Kaiser Co., Oakland, Calif.

. . . . basic oxygen steelmaking in the U. S. has increased greatly in the past few years; however, while much information has been disseminated relating to operational procedure and maintenance, little has been made known relating to the factors involved in vessel size selection and layout of the furnace shop and auxiliary equipment . . . .

THE demonstrated ability of the L-D process to produce steel ingots equal or superior in quality to those produced by most other processes and at a lower cost has resulted in the consideration of plants utilizing the process as part of the future program of many steel companies. There is no standard for these plants; however, there are certain critical areas common to all. Some of these areas are:

1. Furnace size selection.
2. Raw material availability.
3. Scrap handling method.
4. Hot metal handling method.
5. Slag handling method.
6. Gas cleaning method.
7. Flux materials handling method.
8. Teeming aisle layout.
9. Provisions for improved technology.
10. Architectural treatment.
11. Miscellaneous activities which are an integral part of the process.
12. Stand-by provisions.

A complete discussion of the areas mentioned would require a considerable amount of time; therefore, it is proposed to confine the discussion to: (1) a method of selecting furnace size; (2) a technique for optimizing equipment and facility selection in some of the other areas, which will be demonstrated by evaluation of scrap handling; (3) some of the other critical areas listed above; (4) one method of approach to the controversial problem of stand-by equipment and (5) a presentation of composite general arrangement drawings.

FURNACE SIZE

This important area, which is closely related to hot metal availability, largely determines plant capacity. Engineers familiar with this problem have developed the design of over two dozen L-D plants scattered throughout the world. The range of furnace sizes covered in these designs was from 35 to 300-ingot tons and L-D capacities were as high as 2,300,000 tons per year. Although, on the basis of present knowledge of the reactions, the most practical heat size for optimum production seems to be about 150 tons, this cannot be regarded as standard, for a recent design for a certain midwest steel company included a plant having two furnaces each tapping 300-ingot ton heats, yet in another instance two 65-ton furnaces were recommended for a plant.

Some of the major factors involved in the selection of these two widely different furnace sizes should be briefly reviewed. In the case of the 300-ton furnace plant, the client had certain existing open hearth facilities such as a building structure, cranes, ladles and other equipment that could be made available and were adequate for handling the loads imposed by 300-ton heats. Therefore, the possibilities were that this same equipment would be used even if smaller heats were tapped. The available equipment, larger in capacity than required, was too small in number to service more than two furnaces even if smaller than 300 tons in size. In addition, a serious plant area availability problem existed. Consequently, to obtain the desired tonnage output it would be necessary, with smaller sized vessels, for the client to buy a substantial amount of new equipment that would not be well adapted to the existing building structures which might

otherwise have been utilized.

As a result, it became apparent that this particular client could utilize a 300-ton furnace with a much smaller risk than could a client who might consider going to this size with a completely new plant containing all new equipment. Therefore, the client decided that on the basis of evaluation of the estimated capital and operating costs and the risks involved that it was wisest to proceed with the 300-ton furnace plant. This plant, for which the basic design was recently completed, is now under construction. The plant capacity, although estimated, will actually be dependent upon the eventual cycle to be developed for the 300-ton furnace, and this will not be known with any degree of accuracy until the plant has operated a year or more. This plant will provide a very valuable landmark for the industry in determining the capacity of very large basic oxygen furnaces.

The 65-ton furnace plant mentioned above was recommended for entirely different reasons. Consultation with the client developed certain interrelated factors that had to be reconciled to establish furnace size. The more important of these were:

1. Over-all steelmaking capacity from existing open hearth furnaces and new L-D furnaces.
2. Area availability.
3. Hot metal availability now and in the near future.
4. Hot metal charge to the open hearths.
5. Plant scrap balance.
6. Seventh day L-D shutdown because of premium pay on Sunday.
7. Ingot costs from the open hearths and the L-D furnaces.
8. Order size and inventory control.
9. Stripper, soaking pit and blooming mill operations.

Studies were made of all these factors and furnace sizes from 33 to 107 tons were considered. These studies were simplified for an important reason. The L-D plant capacity could be readily predicted because the furnace sizes considered were all within the range for which actual production data were available.

The first result of these studies indicated that furnace size must be somewhere between 52 and 94 tons. The smaller size would require three furnaces to attain the ultimate desired production while only two furnaces would be required for the same production with the larger units. However, neither extreme fulfilled all conditions and after further consideration, a 2-furnace plant tapping nominal 65-ton heats and expandable to three furnaces was recommended and formed one basis of design.

Also, as a result of these studies it was recommended that several of the existing open hearths be removed. This, too, formed a basis of design and allowed for the considerable use of existing structures and equipment.

The foregoing two examples are for plants that are not completely new or "green field" projects and where furnace size was largely dictated by local conditions. Now a completely new L-D facility which, for obvious reasons, is hypothetical will be considered. The existing steelmaking facilities are assumed to be open hearth furnaces and an additional production of 1,000,000 tons per year is required. On the basis of known practice, this requirement can be met by a furnace of approximately 90-ton capacity. This installation would consist of two furnaces, one operating while the other is being relined.

If it is assumed that the marketing forecast calls for an increase in requirements in five years of an additional 500,000 tons to 1,500,000 ingot tons per year, the requirement can be met by a 150-ton furnace, operating one out of two installed furnaces. On the other hand, if the 90-ton capacity furnace was selected and a third furnace added, the capacity would be almost 2,000,000 tons per year or one third greater than the actual requirements.

If it is assumed that the marketing forecast ten years hence calls for the further increase of 250,000 tons per year, giving a total requirement of 1,750,000, the furnace size should be 175 tons for one operating furnace out of two. On the other hand, the addition of a third 150-ton furnace would give an annual production of about 2,700,000 tons per year or almost 60 per cent more than the actual requirement. From the above it can be seen that there is no practical combination of L-D furnaces which will meet immediate and future production requirements.

This is a familiar problem to the steel industry, particularly in the U. S. where, because of the high productivity of many units, it is difficult to obtain relatively small increments of capacity of certain operations.

The inability to obtain precisely the desired capacity increase is further distorted by an anticipated variation in operating rates, which, in turn, affects the operating costs of the unit. For example, whereas the level of general steelmaking operations for the year 1960 averaged about 50 per cent of capacity, the operating level for L-D facilities averaged 80 per cent of capacity. On the other hand, sufficient ingot capacity must be retained to meet the requirements at maximum operating rates. The flexibility necessary can be best obtained by adjusting the open hearth operations.

Therefore, the proper selection of the furnace size is determined by the relative importance of each of the above factors to the particular case. A forecast for five years hence might tend to be more factual than one made on the basis of a longer period because of the hazards of broad extrapolation. On one hand, it is desirable to install facilities that will meet, or can be modified to meet future requirements. From the above data it can be concluded that if the 90-ton furnace is installed the plant is inadequate in the space of five years. On the other hand, if the 150-ton furnace is installed it will be adequate for ten years. Furthermore, in the space of ten years improved technology may be envisioned that will reduce the operating time sufficiently to produce the maximum anticipated tonnage.

On the above basis a furnace of 150 tons should be selected as the optimum capacity to meet forecast requirements for the hypothetical plant.

There is a further concept that should be constantly kept in mind during evaluation of furnace sizes. This concept can be called "furnace utilization" and is determined by the ratio of the actual furnace production divided by its theoretical capacity. The 1,500,000-ton production requirement could be met by installation of any furnace size of 150-ton capacity or greater. If a furnace having a capacity of 2,000,000 tons per year were installed and operated at the lower rate, the utili-

zation would only be 75 per cent. The capital costs and, to some degree, the operating costs would be determined by the capacity rather than by the actual production. Therefore, the unit costs would increase at the lower utilization ratio.

Next, a correlation is made of the effect of the proposed heat sizes with the anticipated order size and with the soaking pit capacity to insure that there are no serious discrepancies due to the furnace size selected.

RAW MATERIAL AVAILABILITY

Since it was established that the primary design consideration be for 1,500,000 tons per year, all traffic patterns, material handling facilities and utilities will be established on this basis. If the hot metal, scrap and flux analyses are accurately known, a heat balance and material balance can be made. On the basis of this material balance, the following are the daily requirements of metallics: hot metal 3300 tons, scrap 1420 tons, mill scale 40 tons, ferroalloys 35 tons. This will result in an ingot production of approximately 4170 tons per day.

The L-D requirement for hot metal of 3300 tons per day may result in reducing the contemplated allocation of hot metal to the open hearth furnace. This, in turn, may affect their production rate. If additional blast furnace capacity by improvements in burden and operating practices, by furnace enlargements or by adding furnaces is part of the program, the open hearth production rate may be either increased or decreased depending upon the change in hot metal ratio. This change can be readily evaluated both from the standpoint of economics and from the standpoint of productivity. In many cases the secondary effect due to the change in hot metal ratio does not appreciably affect the productivity of the open hearth. If this conclusion cannot be reached, the ratio of L-D to open hearth production can be adjusted by linear programming techniques which are described in most references on operations research.

Scrap quantity necessary for the L-D process is evaluated on the basis of present availability of both revert scrap and purchased scrap and the relative suitability for charging into the L-D furnace. It is undesirable to charge extremely heavy sections of scrap such as short ingots because of the limited melting time available. On the other hand, low-density scrap such as wide trimmings or lightly compressed bales should also be avoided since the charge quantity could exceed the furnace volume. Therefore, on this basis consideration should be given to the disposition and availability of the required quantity and size of scrap.

Flux materials availability should be evaluated next and provisions made to store the proper quantities of fluxes for uninterrupted production. If several sources of burned lime of satisfactory quality are immediately available adjacent to the plant site, only limited enclosed ground storage is necessary. On the other hand, if an outage of the local calcining facilities would interrupt production of the L-D plant, consideration must be given to storage of sufficient quantities pending delivery from an alternate source.

On the basis of the information developed, a traffic pattern is prepared showing the number of carloads of material in and out of the plant per day. Investigation is then made of the number of train movements required to move this material. This evaluation is necessary since the traffic flow considerations must be taken during the development of the actual layout.

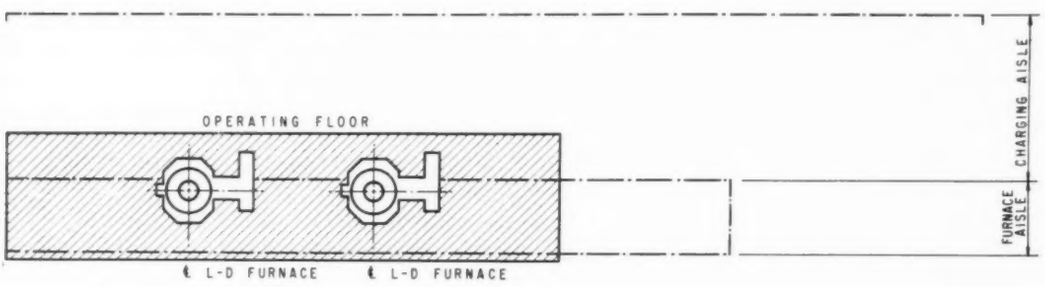
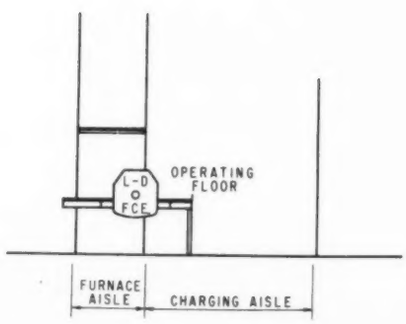


Figure 1 — Furnace placement and aisle width are chosen with reference to previous experience.



PRELIMINARY LAYOUT

With the completion of these basic considerations, preliminary layouts and studies can be made with respect to the practicality of installing facilities in existing buildings, cleared areas or green fields. In the case of adapting to existing facilities, arrangements will be dictated by the restraints imposed. In the event that the green field or cleared site is selected, the furnace aisle is established on the basis of criteria developed above. The charging aisle is laid out so as to handle the required quantity of raw materials.

Figure 1 shows the furnaces located in plan and section. The furnace aisle width has been arbitrarily chosen to be 40 ft-0 in. Previous studies have indicated that this width will permit satisfactory operation with a minimum excess area. The width can be changed later should subsequent conditions dictate. The furnace spacing has been arbitrarily shown as 100 ft-0 in. This space is desirable to provide adequate operating room around the furnace and to prevent interferences from activities associated with rebuilding the alternate furnace. Depending upon local plant bay spacing standards, this dimension can be altered but in no case should be less than 80 ft-0 in. The charging aisle width is shown as 90 ft-0 in. Again, this dimension is a first choice based on experience and must be verified as the drawings develop.

Where a plant is to utilize some existing facilities, as with the previously mentioned projects having 300 and 65-ton furnaces respectively, the problems of layout are much more complicated. Generally, the results are a compromise between capital costs and productivity and operating costs.

SCRAP CHARGING

Following the preliminary layout, studies are made covering all acceptable methods of scrap charging between the proposed method of arrival or storage and the furnace itself. Since the scrap box handled by an overhead crane is a conventional method of scrap charging, it will be used as an example in the following analysis.

A rapid approximation of the scrap quantity required for the charge can be made based on an assumed scrap density which will be taken as 100 lb per cu ft. For the furnace selected the scrap volume necessary per heat will be about 1000 cu ft. The maximum size box that would fit into the furnace and still allow clearance is about six ft sq in cross section. In order to hold the 1000 cu ft, this box must be 28 to 30 ft long. Bearing in mind that the box must be tilted to discharge the scrap, the 30-ft length would require additional building height. Therefore, it is assumed that the scrap charge will be made in two lifts each having a capacity of 500 cu ft. These boxes will be filled by electro magnets and, at one ton per lift, 51 magnet lifts will be required. On the basis of crane operating speeds including acceleration and deceleration, the time for each lift can be established. The boxes must then be transported to the furnace and charged and this, too, can be established on the basis of crane operating speeds. A complete evaluation in accordance with the steps outlined will determine the facilities and equipment required.

With hot metal and scrap both being charged by cranes, time studies can be made showing the time required for charging the furnace including interferences and handling times as they affect the furnace cycle time.

The difference in charging time between this proposed method and other methods studied will have an effect on production. One alternate method may show it to be impossible to maintain the furnace cycle time necessary for the required production. For example, it is conceivable that one method may be to charge the furnace directly by magnet. With this concept it is obviously impossible to maintain the time cycle required.

An estimate is made of the capital costs associated with the proposed facility. This capital cost includes not only the cost of the equipment but also supporting utilities such as switchgear, and includes supporting structures.

An estimate can be made of the manpower required and the other costs associated with operations. This can be prorated to a daily cost.

A reliability index is placed on the proposed method. Generally this must be a judgment figure based on experience gained with similar type equipment and is best evaluated after all the proposed methods have been defined.

Anticipated maintenance may, in some respects, be a corollary to reliability except that maintenance, labor and supplies may be different for each method.

Alternate charging methods are obviously desirable. In the case of breakdown of the scrap charging crane, provisions can be made to charge scrap with the hot metal crane. It is granted that this would increase the cycle time and probably pose some operating inconveniences, but the plant could continue to operate at a reduced rate. This may not be true in other methods.

Having completed the evaluation which can be expanded if desirable, the items for each are assessed in order of importance as shown in Table I. The variations are labeled A, B, C, D, E and F and may represent production effects, capital costs, operating costs, reliability, anticipated maintenance and alternative methods. Arbitrary values are assigned to each variable in order of importance. Assume that the following values are assigned as shown: 100, 60, 55, 44, 34 and 27. This means that the effect of production is of greatest importance. The effect of capital costs and operating costs are about the same and of lesser importance than production. Next, the relative importance of combinations is assessed by a group meeting with the client's engineering, operating, management and maintenance personnel, and decisions are reached with respect to the combinations as shown in Table II. Decision 1 determines if A is of greater importance than B plus C. Decision 2 determines if A is of greater importance than B plus D. Decision 3* determines if B is of greater importance than C plus D. Decision 4* determines if C is of greater importance than E plus F. These decisions shown are only typical and the table is shortened for ease of understanding but all possible combinations are evaluated in practice.

As soon as the decisions have been made, the assessments are re-evaluated and would show some rear-

* Requires change in values.

rangement as in Table III. It will be noted that in this particular example Item B went up in value and the remaining items went down. The relative values of each of the scrap charging methods studied are assigned by using the same procedure. Calling the methods Roman numerals I, II, III and IV, one can give the method ratings for each item in exactly the same way. For example, take operating costs as shown in Table IV. The same general type of analysis is shown for the various systems. In this example, the operating costs are \$1.10, \$1.50, \$1.25 and 75¢ respectively. This would lead to a relative value of 68, 50, 60 and 100. The complete tableau is shown in Table V. For each cell the product of the relative value and relative weight are entered. The column total of these products is a measure of the effectiveness of each system. It can be seen that method I is most effective and method IV is least effective. Methods II and III show the same effectiveness. In this case method III would be selected as the second choice solely because it has a value for variable F. The plant would therefore be laid out on the basis of scrap charging method I.

HOT METAL HANDLING

Hot metal can be transferred from the blast furnace to the L-D plant in various ways, either by open type or by Pugh ladles. Unless the long range planning of the company indicates a change in transportation methods, investigations of hot metal handling should, where possible, be based on utilization of equipment of the same type and capacity used elsewhere in the plant. Consideration of the use of a hot metal mixer as an intermediate step in the hot metal handling involves the operating costs of a hot metal mixer and the net temperature effect. Because of the regularity of production of heats, mixers are not generally required. They increase operating costs and have not proven necessary in providing a more uniform hot metal analysis. Unless other conditions dictate, such as intermittent L-D operations, hot metal mixers are generally not provided. The conventional approach to charging hot metal into the L-D furnace is by overhead crane because of the flexibility of movement. Consideration could be given to alternate methods of handling using the same methods of optimization just discussed.

In smaller size plants hot metal can be poured directly into reladling pits, eliminating a transfer car with its attached capital and operating costs. In the case of larger plants where metal from more than one Pugh ladle is required per charge, material movements recommend that a continuous track be provided for the hot metal. This is best accomplished outside the building necessitating a transfer car to move the material so that the ladle is accessible to the charging crane. Since the 150-ton furnace plant under discussion provides at least one heat per ladle, car shifting is reduced. Setout tracks can be provided outside the building for blast furnace hot metal. Since it is assumed that alternate electric circuits will be provided to the tilt control, the

TABLE I
Initial Assessment

Variable	Representation	Relative weight
A	Productivity	100
B	Capital costs	60
C	Operating costs	55
D	Reliability	44
E	Anticipated maintenance	34
F	Alternative methods	27

TABLE II
Decisions

Variables	Representation	Group Decisions
A > B + C	Productivity > Capital costs + Operating costs	No
A > B + D	Productivity > Capital costs + Reliability	No
B > C + D	Capital costs > Operating costs + Reliability	Yes*
C > E + F	Operating costs > Anticipated maintenance + Alternative methods	Yes*

* Requires change in values.

TABLE III
Reassigned Values

Variables	Representation	Relative values	Previous values
A	Productivity	100	100
B	Capital costs	82	60
C	Operating costs	43	55
D	Reliability	38	44
E	Anticipated maintenance	24	34
F	Alternative methods	13	27

TABLE IV
Variable C—Operating Costs

	Method I	Method II	Method III	Method IV
Operating costs	\$1.10	\$1.50	\$1.25	\$0.75
Relative value	0.68	0.50	0.60	1.00

TABLE V
Complete Tableau

Variable	Relative value	Method I		Method II		Method III		Method IV	
		Relative weight	Product	Relative weight	Product	Relative weight	Product	Relative weight	Product
A	100	1.00	100	0.90	90	0.85	85	0.70	70
B	82	0.90	74	1.00	82	0.80	66	0.70	57
C	43	0.68	29	0.50	22	0.60	26	1.00	43
D	38	0.80	30	0.70	27	1.00	38	0.90	34
E	24	0.90	22	1.00	24	0.70	17	0.80	19
F	13	0	...	0	...	1.00	13	1.00	13
Effectiveness	...	...	255	...	245	...	245	...	236

A = Productivity; B = capital costs; C = operating costs; D = reliability; E = anticipated maintenance; F = alternative methods.

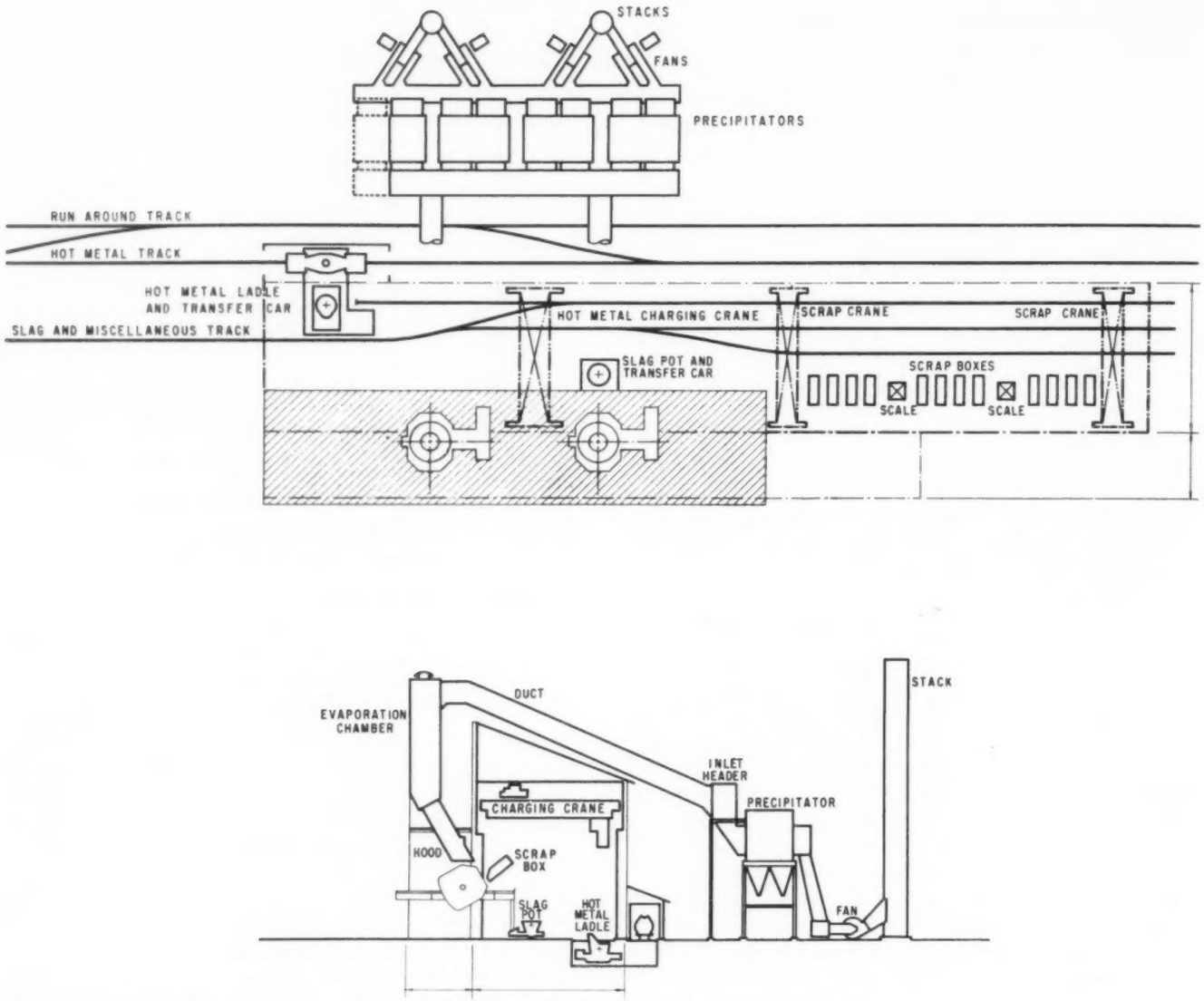


Figure 2 — Layout shows the addition of charging aisle and gas cleaning facilities.

only failure would be in the scale proper. Hot metal can be provided in an emergency, without direct weighing, by visual measurement of the height of the liquid in the transfer ladle.

SLAG HANDLING

From the material balance previously prepared, the slag quantity is 20 tons per heat or between 325 and 350 cu ft. The current slag handling practices in the client's plant are evaluated to determine if the existing slag pots will meet the requirement of accommodating all the slag from a single heat. Consideration must be given to the effect of the additional quantity of slag on the present slag disposal facilities. If these are being strained to capacity, alternate methods of slag disposal are evaluated including slag granulating facilities. On the basis of local costs, the minimum cost method is selected. For the hypothetical plant it is assumed that current practice uses 400-cu ft pots, trunnion mounted, for disposal at a slag dock. In order to avoid additional duties in the teeming aisle, furnace slag is handled in the charging aisle. Since it is necessary to interchange slag pots between the disposal cars and the transfer cars by overhead crane, area must be provided in the charging aisle for this operation. In addition to the necessary trackage, ground storage space must be provided for emergency use. Since the area in the charging aisle is limited it appears that the direct charging of hot metal into the transfer ladle in the furnace aisle should be reconsidered. Despite the advantages of eliminating the transfer car, its addition appears to be necessary from space considerations. In order to provide for emergency pouring of hot metal, the slag track is located adjacent to the hot metal transfer car pit so that the material can be poured from a car resting on the slag track.

GAS HANDLING

It is conceivable, although unlikely, that a plant can be installed in this country without gas cleaning facilities. The gas volumes directly evolved from the furnace are calculated using the quantities shown on material flow diagram and upon the instantaneous CO to CO_2 relationship. This instantaneous value is

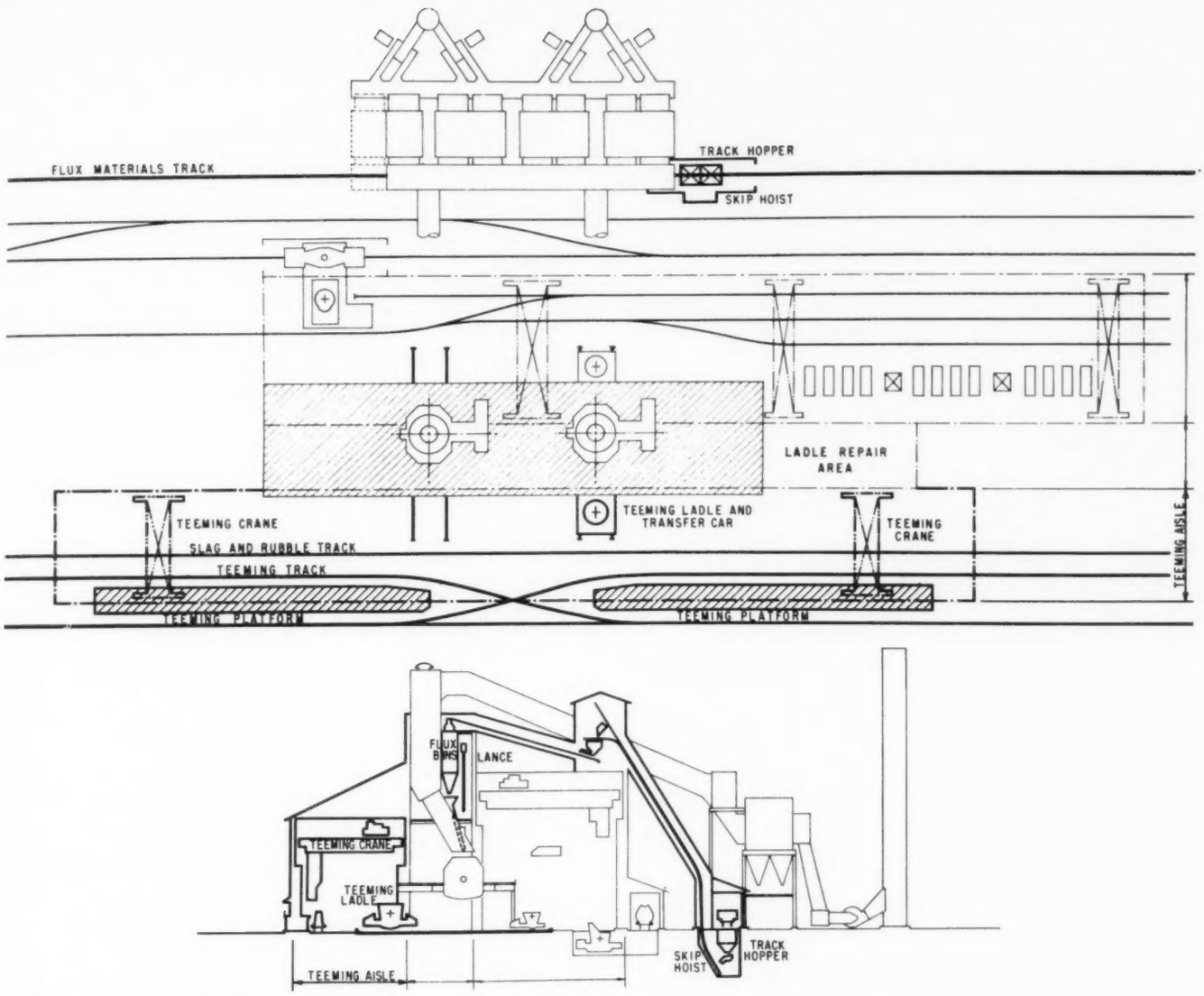


Figure 3 — A teeming aisle which allows for a 25-min teeming time and a 35-min holding period has been selected.

used since any gas handling equipment must be designed to handle peak conditions. Criteria for gas cleaning efficiency are established based on local codes and public relations policies. The fume and dust generation is a result of two factors: mechanical ejection and condensation of metallic vapors. These latter particles are as small as 0.1 to 0.01 micron. This dust can be cleaned by a number of methods such as electrostatic precipitators, bag filters, venturi scrubbers and disintegrators. Investigation is made of the relative capital and operating costs of each method when operating to the required degree of efficiency. Further consideration must be given to the possibility of a requirement for an increase of efficiency and the relative effects of this increase on the space requirements, as well as on the ultimate capital and operating costs. Methods of disposal of the collected material must also be considered. On the basis of these considerations, the gas collecting system is selected. The hypothetical plant under discussion assumes a requirement of 95 per cent efficiency expandable to +99 per cent. It also assumes relatively high power cost and a shortage of water. Under these conditions an electrostatic precipitator has been selected. As shown in Figure 2, the charging aisle has been added and the gas cleaning facilities have been added.

FLUX MATERIALS

The flow diagram indicates the flux materials to be handled. In most cases it is preferable to store materials in overhead bins to be fed into the furnace by gravity. This allows a factor of safety in the event of handling equipment failure. Since material can arrive in trucks or hopper cars, provision is made to handle material arriving by either method. Material handled to the overhead bins by belt conveyor permits a uniform flow of material, however the conveyor must be in a gallery protected from inclement weather. Alternate methods are handling by means of skip hoist or pneumatically. Each has its operating advantages and disadvantages. Optimum selection can be made using the same methods as illustrated for scrap handling. The hypothetical plant has assumed that space is at a premium; therefore, a combination skip hoist and belt conveyor system has been selected. Material will be fed from the bin to

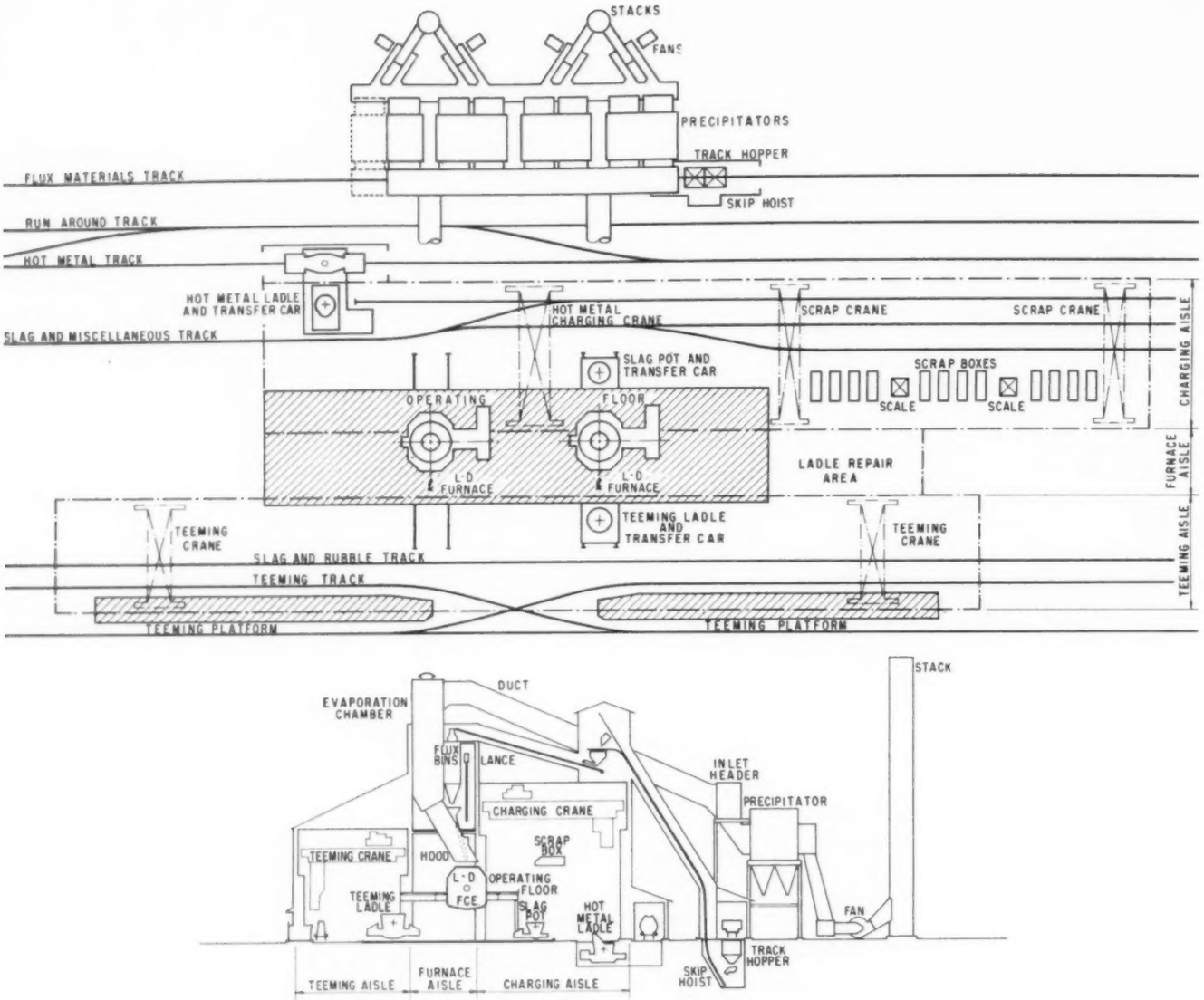


Figure 4 — The composite cross section of the L-D plant indicates all the necessary operational equipment.

the furnace by belt conveyor. Bins are shown conveniently located between the furnace hoods.

GENERAL REVIEW

On the basis of the information developed thus far which affects the charging aisle and furnace aisle layout, drawings are re-evaluated to determine if the arrangement as presented necessitates changes to any of the conclusions developed so far regarding furnace size, scrap handling, hot metal handling, slag handling, gas cleaning and flux handling.

TEEMING AISLE

A thorough study of teeming operations must be made for each plant because of the difference in metallurgical practices. These practices primarily deal with the grades and size of ingots, teeming time and holding time. If a drag can be moved immediately after teeming, no holding area is required at the teeming platform. Platforms must be laid out so that the required metallurgical times are available, and so that a free platform is available when necessary. This study is most often graphically presented where horizontal movements and operating times can be shown. Consideration must also be given to the various services which must be performed such as ladle relining, stopper rod and nozzle replacement, refractory storage and disposal of teeming ladle slag. In some cases the above considerations require the installation of parallel teeming aisles with material moved between aisles by transfer car. Figure 3 shows a teeming aisle which was developed for a 25-min teeming time and a 35-min holding time.

MISCELLANEOUS REQUIREMENTS

Although certainly not unimportant, the following should not dictate equipment arrangement but must be considered and so arranged as to facilitate plant operations and have no adverse effect on heat time: lance manipulation; lance storage and repair; ferroalloy handling including crushing, storage, weighing and discharging; method of furnace rebuilding; offices and sanitary facilities; and miscellaneous services.

Another item is plant cleanliness, particularly connected with the flux handling system where provision should be made to prevent the accumulation of dust in relatively remote areas.

PROVISIONS FOR IMPROVED TECHNOLOGY

The plant layouts must provide space for additional equipment needed by virtue of improved technology. Great strides have been made since the pilot work was done on the L-D process ten years ago, and it is reasonable to expect that progress will continue. The following are some of the areas for which the surface has only been scratched and long strides are expected in the future: computers for process calculation, computers for process control, automation, change in technology to permit even higher scrap ratios and data accumulation systems.

FINAL LAYOUTS

Preparation of the final complete general arrangement drawings with review to insure that due consideration has been given to secondary problems as well as the primary problems developed above. These include ventilation, lighting, heating, snow, weather protection and waste disposal.

STAND-BY EQUIPMENT

Although certain stand-by equipment appears on the surface to be highly desirable, each item should be evaluated on the basis of economic justification, considering capital and operating costs, reliability and cost analysis of potential production losses. The following is one technique for making such evaluations:

If the hot metal crane breaks down, no alternate source of hot metal is available to the furnace, therefore operations must be suspended.

Although the purchase price of a crane of the required capacity is approximately $600,000, it might be concluded that this is a good investment. However, an analysis of hot metal crane availability indicates that this particular crane has an availability of 98 per cent, and it can expect to be idle only two per cent of the time.

There are several methods of calculating the cost of capital necessary for the purchase of the crane. For example, the investment may be taken as a 3-year write-off which is comparable to the over-all write-off of an L-D plant based on operating cost savings, or on a 10-year write-off. Assuming a 10-year write-off with a straight line depreciation and 5-per cent interest on the undepreciated balance, the average annual cost of this capital is $77,700 per year without taxes, insurance or operating costs. This capital must be regained from additional crane availability or, in other words, tonnage which otherwise could not be made. Based on a $10 per ton net profit, 7770 tons of steel must be sold in order to repay the investment. This, for the hypothetical plant, is equivalent to almost two days' production and represents a crane outage of 0.5 per cent. However, the type of outage has a great effect on crane availability and most of the crane outages can be planned for such times as not to interfere with operations. Changing brake shoes, replacing contacts and re-reeving generally can be scheduled. Data from one L-D process plant indicate a crane availability for a three-month period of 99.98 per cent. This obviously, from the standpoint of economics alone, will not justify the second crane.

THE BEGINNING

All the work accomplished so far has merely given the basic start to the problem and has, so to speak, established the ground rules. It has further defined the scope of work of the project. Details must be worked out and further problems solved as design progresses, see Figure 4. Decisions will be required concerning stopper rod oven design and arrangement, relocation of various items of equipment and facility to suit operator preferences and minor modifications in the interest of economy, either capital or operating.

The scope of L-D layouts has been briefly touched upon and methods of solution to the interrelated problems have been offered. As with most techniques, these are most effective when applied with judgment and with experience.

Discussion

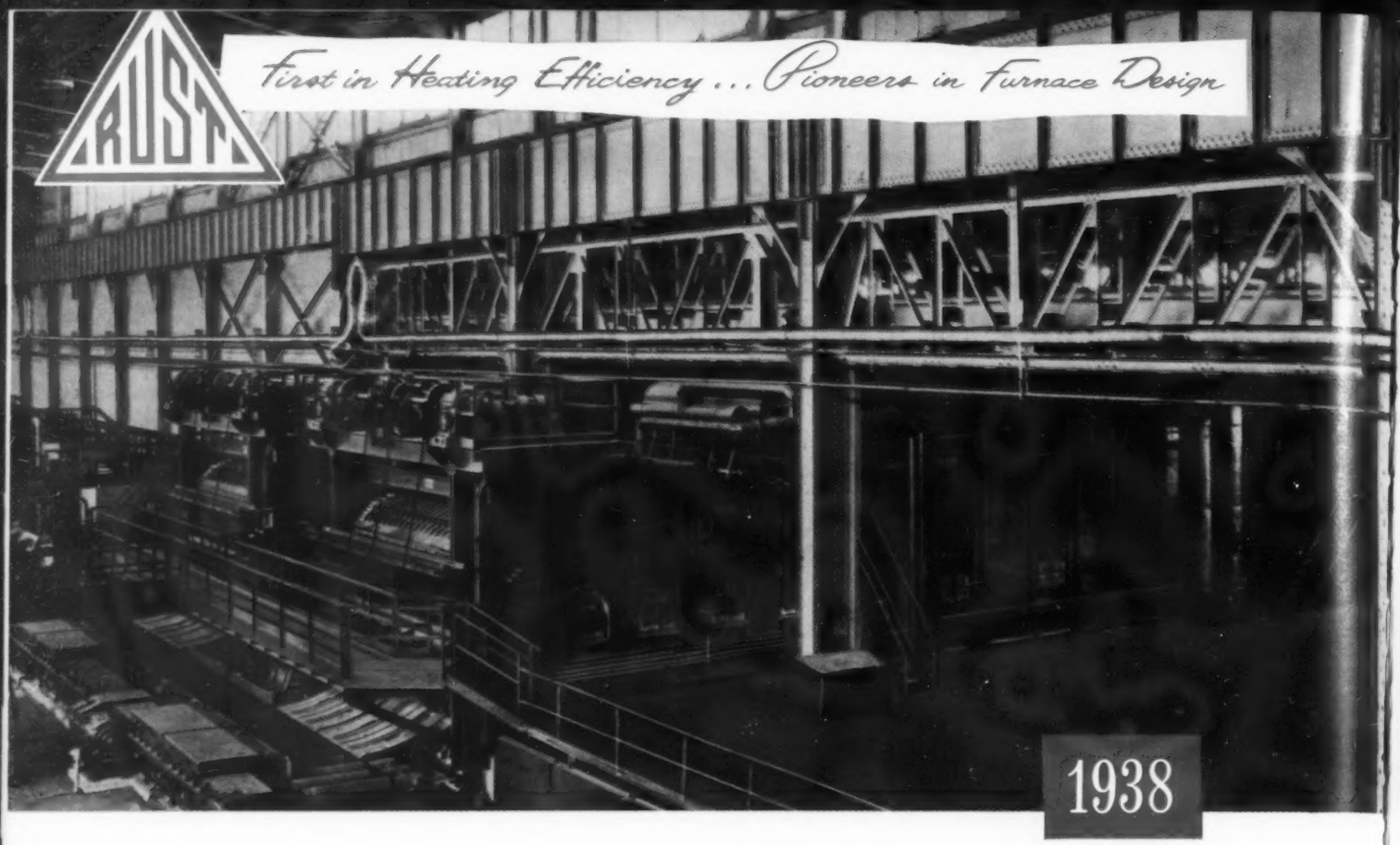
PRESENTED BY

MICHAEL S. MONTALBANO,
Formerly Manager,
Research & Computer Planning,
Kaiser Steel Corp.,
Oakland, Calif.

Michael S. Montalbano: Making technological innovations which require substantial capital expenditures is a matter requiring the most careful consideration. This paper makes available many useful results derived from a reasoned examination of years of experience with the design and installation of L-D plants.

Design considerations are usually hard to objectify. Good design frequently comes from the experience of the designer by a process which he himself would find it hard to describe. The author's paper is particularly interesting in its description of methods of making certain design considerations quantitative, consistent and, thus, objective. His discussion of how to determine the relative numerical values of such design factors as "productivity, capital costs, operating costs and so on" is akin to the derivation of a "utility function" in modern economic theory. It is a first step away from the subjective way in which such decisions are usually made. So, too, is his regrettably brief reference to the application of linear programming to the determination of optimum L-D and open hearth production ratios in a shop with limited hot metal.

A further discussion of quantitative approaches to the L-D plant layout problem, amplifying some of the suggestions made by the author, would be a very welcome followup. ▲



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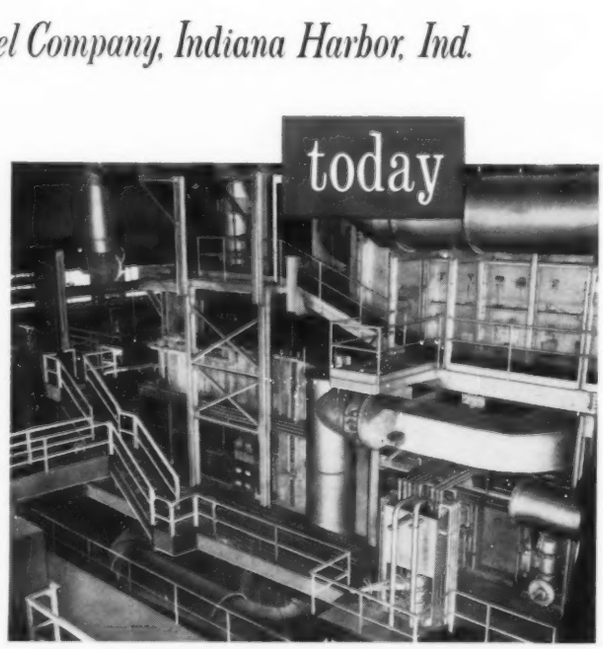

Modern four-zone continuous furnace for heating slabs at a large eastern steel mill.

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F 30

Blast Furnace Coal Injection Offers Promise

AN important new break-through in iron production technology is indicated by the results of using coal to partially replace coke as a blast furnace fuel.

Preliminary findings of small-scale experiments have been supported by further experience with a solid fuel injection system on a commercial blast furnace. This installation is at the plant of The Hanna Furnace Corp., a subsidiary of National Steel Corp. Bethlehem Steel Co. is participating with National in the research venture.

Much additional experimental work remains to be done but the experience thus far gives firm indication of:

1. Substantial savings in the cost of blast furnace fuel.
2. Additional savings from a reduced need for investment in coke-oven capacity.
3. Improved operating efficiency.
4. Higher production with no increase in furnace size.
5. Ability to use the abundant lower quality noncoking coals instead of the more scarce and costly metallurgical grade now required in blast furnace operation.

Although the new development causes a net reduction in the total amount of coal used in a blast furnace, it will have a beneficial effect on the coal industry because it provides an answer to the competitive threat of natural gas and fuel oil as alternate blast furnace fuels.

In addition to its direct technical advantages, the coal injection system promises contributions of a more general nature which are also highly important. Lower cost iron will translate into savings in the cost of steel production. This will give badly needed help to the American steel industry's position in world markets which has been weakened by the disproportionate increase in costs compared with the costs of foreign steel producers.

Also, coal is an abundant source of energy, and would be readily available within the borders of the U. S. in the event of any emergency which created a scarcity of natural gas or fuel oil.

Coal for the injection system is crushed and screened to minus $\frac{1}{8}$-in. size and then conveyed by a vacuum system to an overhead storage tank. The coal is passed under pressure from the storage tank to a charging vessel where it is kept in a fluid condition by compressed air agitation. Metered quantities of the coal are delivered from the vessel through a system of tubes to stainless steel lances at the tuyères through which the coal is injected into the blast furnace.

In the first stage of experimentation with the coal injection system coal use amounted to ten per cent of the normal coke requirement. Currently, coal use has been stepped up to 20 per cent and will be increased to 30 per cent within the coming month. Coal replaces coke on an approximate ton-for-ton basis. In modern blast furnace practice, without using injected fuels, from 1300 to 1500 lb of coke are consumed per ton of pig iron produced.

So far the only coal tested has been low-volatile bituminous coal. This phase will be continued through August and in succeeding months the research program will include tests of high-volatile bituminous coal and anthracite coal.

The direct savings from replacing coke with coal will vary with different blast furnace plants because of location and other economic factors but in any case should prove worthwhile. As to the saving in investment, it was estimated that the cost of a coal injection system would range between 20 and 25 per cent of the cost of equivalent coke-oven capacity.

The comparative advantages of coal, natural gas and fuel oil as alternate fuels for coke in blast furnace operation would be determined by economic factors with plant location the most important.

Coal injection is the latest in a series of developments which have been made on an accelerating basis in recent years to improve the efficiency and increase the production of blast furnace operations. These include the careful selection and preparation of coals, improvements in the physical characteristics and sizing of coke, sintering and pelletizing of iron ore, high top pressure, higher blast temperatures, use of oxygen to enrich the hot air blast and precise control of moisture.

In combination with these improvements, coal injection will contribute further technical progress through its production of richer gases in the hearth area which speed up furnace reactions and increase operating efficiency. It was predicted that optimum results will be obtained through the use of uniformly sized burdens, higher blast temperatures and oxygen enrichment. ▲

Photo courtesy of Green River Steel Company

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Koppers New Research Center Is Dedicated

KOPPERS newest and largest research facility, representing an investment of $8,500,000, was dedicated on August 28.

Koppers began to accelerate its research program about 15 years ago when it moved into chemicals and plastics. Until that time the company had been largely identified with engineering and construction, mostly in the steel industry; coal by-products; wood preserving; fabricated metal products and merchant coke plants.

Koppers new facility, which will be the headquarters of the company's research dept., is described as one of the most advanced in the country.

Only about one third of the buildings planned for the 176-acre site have been completed. No firm schedule for construction of the remaining buildings has yet been set.

The center will eventually be able to house over 1500 scientists and their assistants, about four times its present population.

The many research sections located at the center include the engineering and coke research section and the metal products research section.

The metal products research section has developed an irrigated electrostatic precipitator which can be used to clean the fumes issued by steelmaking processes. However, smoke control is just one area of interest to this group. They are also concerned with ways and means to quiet industrial noises, improve machinery for making large castings and the study of special problems.

The majority of the work of the engineering and coke research section centers around improving the operational characteristics of coke ovens and blast furnaces.

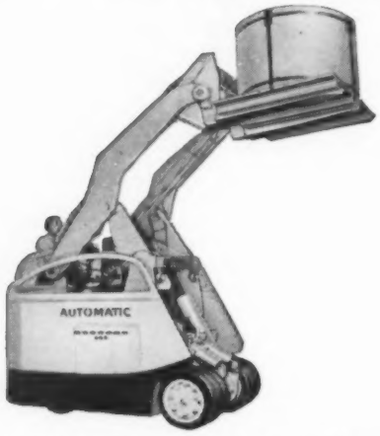
Because of the tremendous investment in primary steelmaking and auxiliary facilities, this section is vitally interested in any increase in coke or pig-iron capacity and production. Constant studies are conducted upon coke-oven wall design and upon refractory design and physical properties, and these efforts are directed toward improving the heat transfer rate to the coal being coked. In line with coke production, the methods and efficiencies of coal chemical recovery and utilization through chemical recovery or by-product ovens is another area of interest.

Physical, chemical and coking properties of coking coals are under constant evaluation to find the optimum blends. Pilot plant ovens test these blends under imulated production conditions. Another project is aimed at developing a uniform sized high quality coke for the blast furnace.

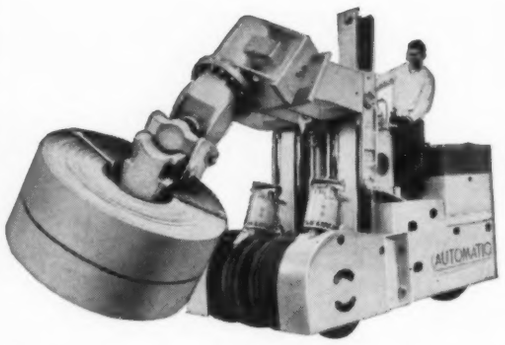
This section also deals with the pelletization of iron ore for the blast furnace charge. ▲

Figure 1 — The center has been designed to permit ease of expansion when additional research facilities are needed.

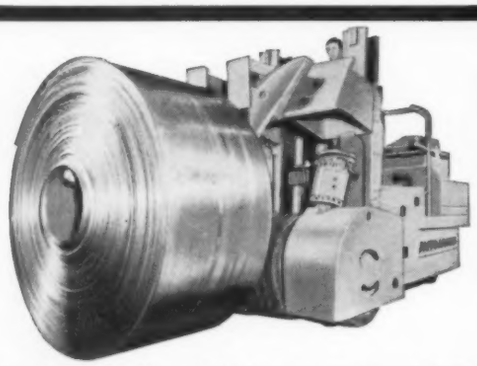
LOWEST COST WAY TO HANDLE COILED STEEL



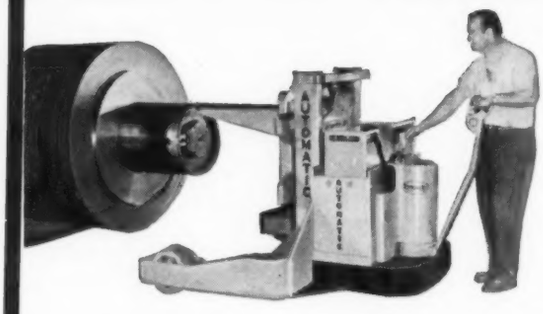
Exclusive Elbolift is most compact, most maneuverable heavy duty truck in its capacity range of 12,000 to 25,000 lbs. Loads coils in boxcars, positions coils on flat-bed trucks in one operation, stacks 120" high.



It's a mobile coil up-ender! Unique wrist-action rotating up-ender and clamp picks up horizontal or vertical coils and rotates them to opposite position. Clamp prevents telescoping. Capacity to 60,000 lbs.



Heavy Duty Giant is available in capacities from 20,000 to 100,000 lbs. This capacity range permits strip mills to roll larger, heavier coils to boost production and lower costs.



Heavy Duty Transporter with coil handling ram is ideal for jobs which involve close quarters, short distances, and intermittent use. Capacity to 20,000 lbs. in pallet, platform, fork or ram models.

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HEAVY DUTY TRUCKS

IN CAPACITIES TO 100,000 LBS.

No other handling equipment gives you the mobility and flexibility of heavy duty lift trucks. You can handle loads anywhere in the plant—even into boxcars—without transferring the load to other equipment. With a lift truck, handling usually is a one-man job. What's more, lift trucks adapt easily to production changes.

Automatic brings you all of these advantages with trucks designed specifically to handle coiled steel weighing up to 100,000 lbs. There are models with hydraulically-adjustable rams, fork lift models for palletized coils, high lift coil stackers and walkie models for intermittent use over short distances. A new bulletin tells how heavy trucks can be profitably used in the steel industry.

Write for your free copy of Heavy Duty Trucks Facts and Factors today.

AUTOMATIC AUTOMATIC TRANSPORTATION COMPANY
Division of The Yale & Towne Manufacturing Co.
47 W. 87th Street, Dept T1, Chicago 20, Illinois

Pittsburgh Steel Charts Future Improvements

PITTSBURGH Steel Co. has initiated a 5-year program of capital improvements designed to attain substantial reductions in steelmaking costs. The program consists primarily of:

1. Ownership participation with other steel producers in an iron ore project located at Wabush lake, Labrador, Newfoundland. The Wabush lake property is one of the largest iron ore bodies on the North American continent. A pilot-plant operation has demonstrated that approximately 2½ tons of Wabush ore can be beneficiated to one ton of a 64 per cent iron concentrate. Although final design specifications and ownership interests have not been firmly set, it is expected that the capacity of the concentrating plant will be between 5,300,000 and 6,000,000 tons per year, of which Pittsburgh Steel will be entitled to take approximately ten per cent. When fully operative in 1965, the project will provide the company with a substantial portion of its requirements for a 50-year period at significant cost savings.

2. Construction of a sintering plant for further processing of iron ore concentrates.

3. Construction of two new oxygen converters for making steel at the Monessen plant. The oxygen converter, with its attendant cost savings, is a significant technological advance in the art of steelmaking.

4. Installation of two additional stands to the 4-stand finishing train at the company's hot rolled sheet mill at the Allenport plant. These new stands will significantly increase the productivity of the mill in making it possible to roll the heavier and wider coils demanded by customers. Further, the use of heavier slabs will reduce slab rolling time at the blooming and slabbing mill and save scrap losses in slab conditioning at the rolling mill.

5. Installation of new furnaces and other facilities for annealing cold rolled sheets. With these new facilities added to present annealing equipment, the company will be able to furnish additional tonnages to the growing cold rolled sheet markets. Heretofore, the high capacity cold mill was restricted because of limited annealing facilities.

The foregoing program is designed to reduce the company's raw material and steelmaking costs and thus to achieve increased earnings, and to increase the company's productivity and ability to meet customer demands for a wider range of products.

In order to accomplish this program, new long-term financing will be required. It is contemplated that this financing will be obtained by:

1. From the sale of additional common stock, $10,000,000.

2. From the sale to an institutional investor at par of an additional series of first mortgage bonds, $10,000,000.

The proposed arrangements contemplate, among other things, that the bonds will bear interest at the rate of six per cent per annum, will mature in 1978 and will be subject to a sinking fund commencing in 1966. As additional consideration for the purchase of the bonds, the company proposes to issue to such institutional investor warrants to purchase 200,000 shares of the company's common stock at any time prior to January 1, 1979 at $17 per share. At present, the company has $29,250,000 of first mortgage bonds outstanding.

3. A $15,000,000 bank credit agreement, any or all of which is to be convertible in December, 1963, into a 5-year term loan maturing in December, 1968. The proposed agreement will replace the present $10,000,000 bank credit agreement which expires during 1961.

The arrangements made for the sale of the additional first mortgage bonds and to expand the bank credit agreement will be subject to certain conditions, including the authorization, sale and issuance of the common stock contemplated, and the consent of the holder of the outstanding first mortgage bonds.

At present, the company's common stock capitalization consists of 2,500,000 shares authorized, of which 1,586,595 shares are issued and outstanding, and an additional 44,238 shares are reserved for issuance under the company's 1951 stock option plan. The Board of Directors has approved, subject to the approval of the shareholders, a proposal to increase the number of authorized shares to 4,000,000 shares. Following the increase in the number of authorized shares, the company proposes to sell sufficient shares (in addition to the 200,000 shares to be reserved for the exercise of warrants to be issued with the new first mortgage bonds and in addition to the 72,000 shares to be required for the company's incentive stock option plan of 1961) so that the company will realize approximately $10,000,000 for the purpose of its capital improvement program. ▲

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in Electrical Construction, in Steel Mills, Automobile Manufacturing Plants, and in Heavy Industry . . . .

• Capital investment equipment starts producing sooner when the Murray organization is executing your construction projects. In a diverse field of industrial activity, Murray-Men are making a reputation for completion of contracts substantially ahead of schedule. This is an important factor in planning for increased productivity. You will find it to be good business to include Murray in your plan for future expansion.

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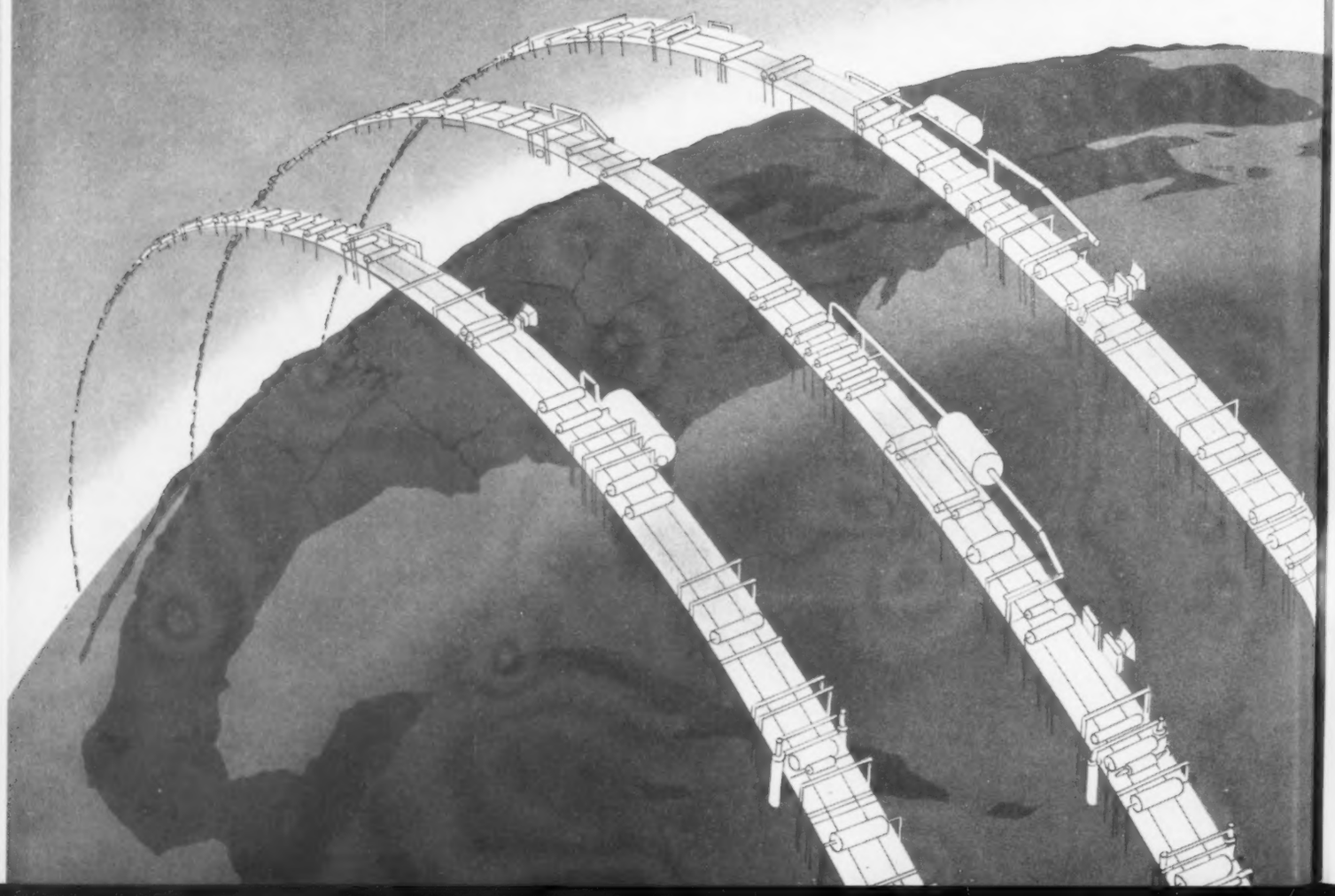


Bethlehem Controls Air Pollution

ELECTROSTATIC precipitators, designed to reduce discharge to the atmosphere of dust and smoke from open hearth furnaces using oxygen injection, will soon be in service at Bethlehem Steel Co.'s Sparrows Point and Lackawanna plants.

Installation of the high-efficiency precipitators is a major phase of the company's multi-million dollar program to assure a cleaner atmosphere in the vicinity of the two plants.

At Sparrows Point the first precipitators are expected to be operative in October; at Lackawanna the initial units will go into service in September.

Under the new system, the waste gases or smoke from the furnaces, instead of passing directly into the stacks, will be drawn through the precipitators and the minute red dust-like particles will be removed instead of being released to the atmosphere.

The dust-laden gases are passed through a high-voltage electrical field where there is imparted to the dust particles a negative surface charge. The negatively-charged dust particles migrate to the oppositely-charged collecting electrode where the charge dissipates and the dust is collected (precipitates). The dust is then dislodged from the collecting electrode by rapping, falls to the precipitator floor, is gathered into a storage bin and removed to a disposal area.

At Sparrows Point the six precipitators will clean the waste gases from seven open hearth furnaces in No. 4 shop where oxygen lances are being installed. After passing through waste heat boilers, the gases are drawn into a single main 850 ft long and from this main flow into the precipitators. These six will handle a total of 948,000 cfm of gases which, after cleaning, will discharge through new stacks 167 ft above ground.

The Lackawanna installation is basically similar to that at Sparrows Point. Three open hearth furnaces are being serviced at the No. 2 shop and six at the No. 3 shop. The precipitators at the former will clean a total of 480,000 cfm of gases while those at the latter will clean 700,000 cfm. Cleaned gases from the precipitators will be exhausted through stacks about 116 ft above ground.

The efficiency of the precipitators at both installations will be better than 95 per cent. ▲

Figure 1 — The heavy fumes caused by oxygen lancing will be cleaned by precipitators operating at better than 95 per cent efficiency.

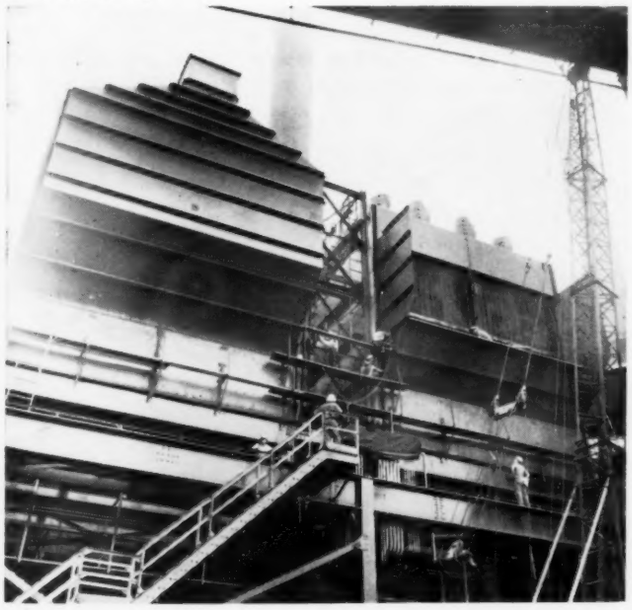
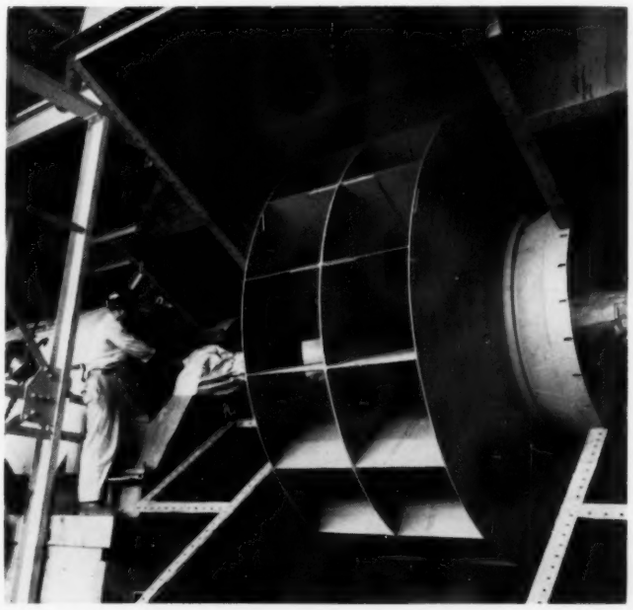


Figure 2 — Large fans, up to nine ft in diameter, will force the fumes into the precipitators.



A-C, D-C Crane Combines Economy and Performance

THE heavy-duty overhead crane, used for industry's wide range of material handling needs, is making economical use of the ready availability of a-c power while retaining the advantages of d-c hoist performance which has made the d-c machine popular and successful throughout the years. The d-c hoist controller, with self-contained rectifier, is a development of the EC&M Div. of Square D Co.

This d-c hoist control system uses a self-contained static rectifier to supply approximately 300 volts for the hoist motor. From long experience with hoist requirements, the designer knows the inherent speed-torque characteristics of the d-c series motor, and how the flexibility of this motor is applied with suitable gearing to meet the specifications of capacity, hook speed and also duty cycle.

Basically, the d-c series motor adjusts itself automatically to varying load conditions. Light loads are hoisted at high speed, up to 2½ times full load speed. With heavy loads, the motor develops more torque at slower speeds. Overloads are readily handled. All loads are safely lowered by a simple, all-electric dynamic lowering circuit.

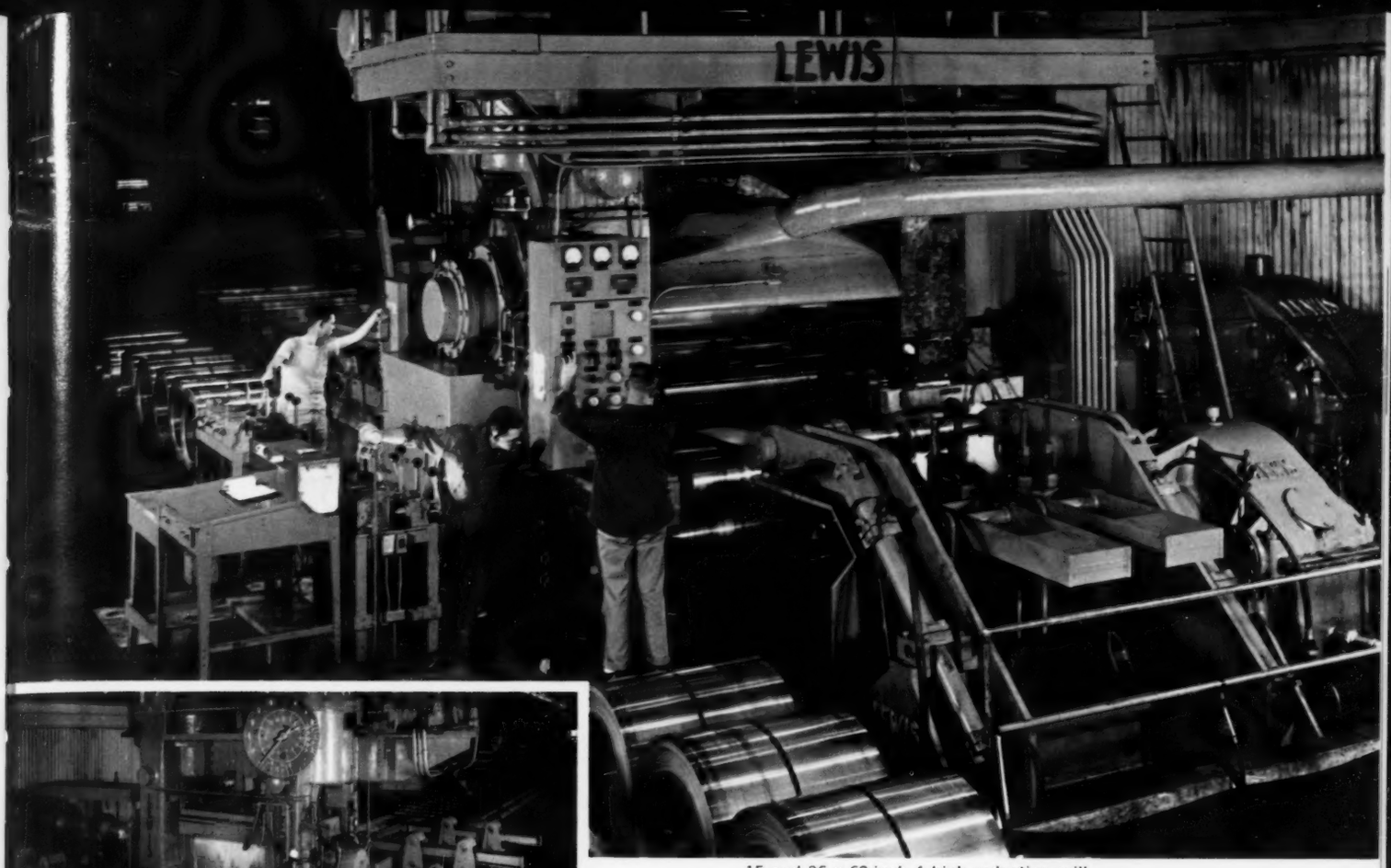
From an operational viewpoint the over-all simplicity of the crane and its control is beneficial. Fewer collector bars and sturdy, magnetic control components are proved factors in lower maintenance costs. There are no complicated circuits to master. Fast response and all speed points under direct control of the operator results in accurate spotting and exact load positioning.

On the surface, the most obvious change is the use of a d-c hoist motor and d-c controller on an otherwise a-c powered crane. The trolley and bridge travel motors are a-c wound-rotor type and, working against a load at all times, are accurately regulated by magnetic controllers having acceleration and plugging functions controlled by frequency relays. The d-c hoist motor, operated from the rectified 300-volt supply, performs better than when operated from a 230-volt shop bus. Light load lowering speeds are faster and stability when lowering heavy loads is greater. The use of series motors and series-wound brakes are recognized as the safest for hoists.

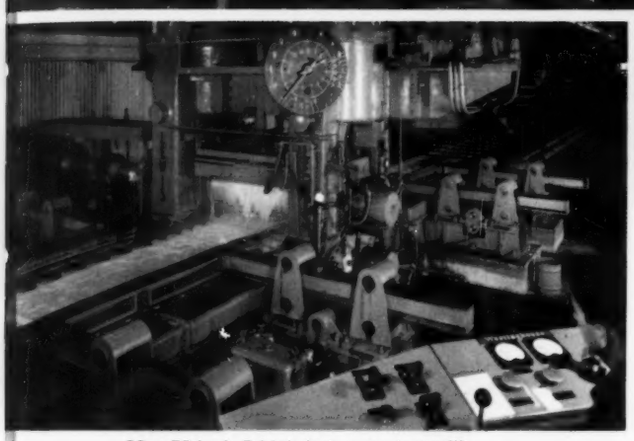
In additional to this gantry crane, the main hoist of whirley cranes at shipping ports and several industrial cranes are operated by this hoist control system. By using the advantages of d-c hoist performance, the cranes have proved to be fast producers with economical advantages of simplicity, safety and low upkeep. ▲

Figure 1 — D-c hoist motors are combined with a-c trolley and bridge motors to produce an efficient design.

Figure 2 — The hoist control system uses a self-contained static rectifier to provide the d-c motor supply.



15 and 36 x 69-inch 4 high reduction mill.



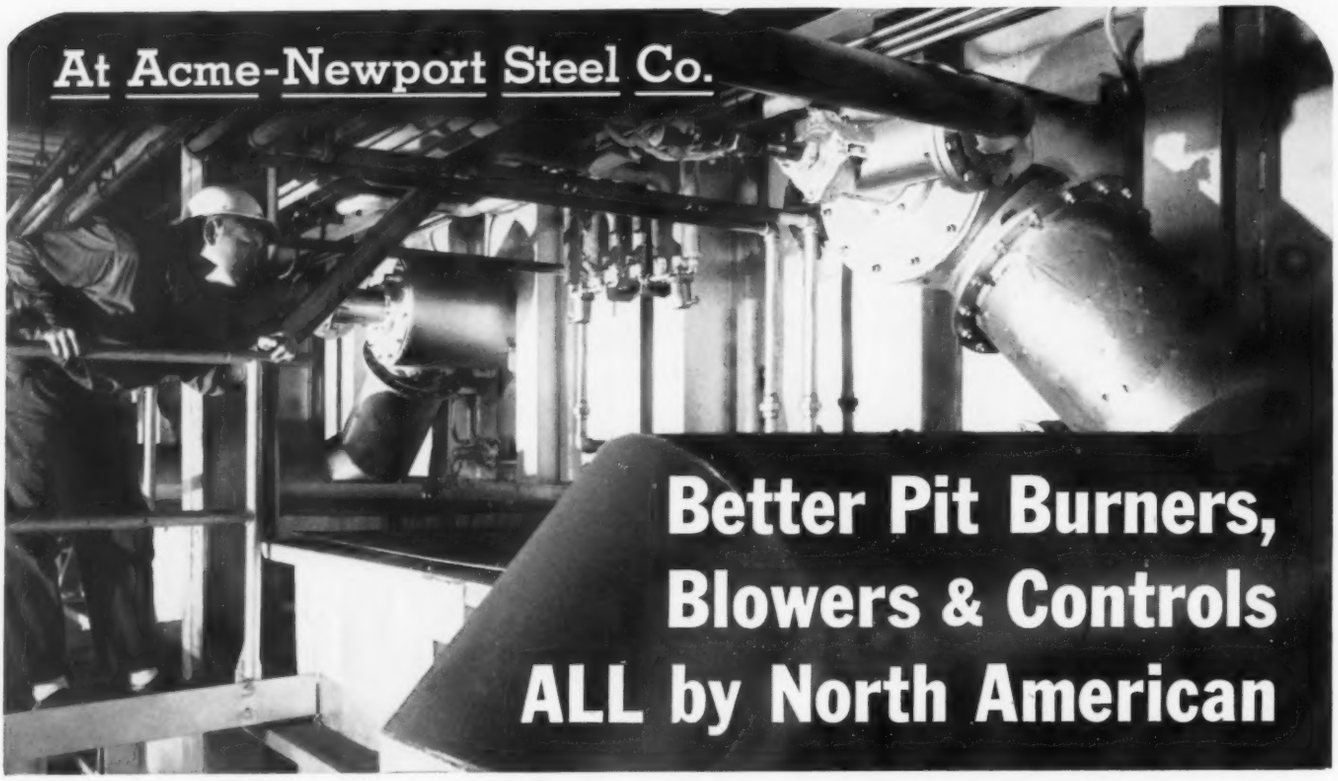
30 x 70-inch 2 high hot reversing mill.

BLAW-KNOX ALUMINUM REDUCTION MILLS

Blaw-Knox designs and builds a full range of mills for the reduction of aluminum and other non-ferrous metals. Other Blaw-Knox equipment for the metals industry includes: Complete rolling mill installations and auxiliary equipment for ferrous and non-ferrous metals: • Sheet and strip processing equipment • Electrolytic tinning, annealing and galvanizing lines • Seamless pipe and tube mills • Draw benches, and cold draw equipment • Blaw-Knox Medart cold finishing equipment • Iron, alloy iron and steel rolls • Carbon and alloy steel castings • Fabricated steel plate or cast-weld design weldments • Steel plant equipment • Heat and corrosion resisting alloy castings. Blaw-Knox Company, Foundry and Mill Machinery Division, Blaw-Knox Building, Pittsburgh 22, Penna.

BLAW-KNOX

Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms • Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes • Towers and Special Structures • POWER: Power Plant Specialties and Valves



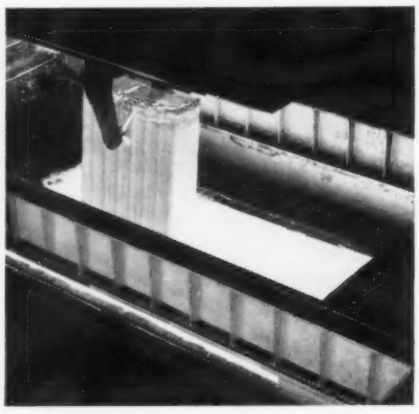
Better Pit Burners, Blowers & Controls ALL by North American

Four one-way over-fired soaking pits built by Industrial Furnace Co. of Salem, Ohio are fired with North American Refractory-lined Dual-Fuel Burners. One pit now uses preheated air—others can be quickly & economically changed by simply exchanging burner internals & adding a recuperator in the flue. A 50 ton cold charge can be ready to roll in 6 hours; a 75 ton charge with 2½ hours track time, in 4 hours, using 700,000 Btu/ton with hot air —900,000 with cold air.

Even heating, correct atmosphere, & economical operation result from North American's hydraulically operated controls for furnace pressure, gas/air and oil-steam/air ratio. These were manufactured, calibrated, pre-piped, wired, and mounted on the panel with their dial operators by North American.

Sturdy Turbo Blowers have air flow controls on inlets—crank type cylinders on butterfly valves. Note air metering orifices above. Last blower feeds a recuperator.

This superior system was provided by the North American Mfg. Co.—the only firm in the world that designs, manufactures, and engineers complete combustion & control systems. If you want better burners, blowers & controls, call your nearby North American Combustion Engineer, or write



The four new pits are 8′ x 20′ x 10½′ deep to coke line. Operators like them because of (1) very fast recovery, (2) no delays in drawing, (3) no detriment to steel from long holding, (4) no washing of ingots, (5) uniform temperature from end to end of pits, (6) uniform heating from tops to bottoms of ingots.

NORTH AMERICAN for COMBUSTION and Hydraulic Controls

The North American Mfg. Co.
Cleveland 5, Ohio

Exhaust System Handles Sulphuric Acid Fumes

SAFE, efficient, economical and maintenance-free removal of fumes from sulphuric acid pickling operations has always presented many difficulties. These difficulties can be overcome, and the desired objectives obtained, by removing the fumes through duct systems built of plastic materials having the necessary chemical and physical properties.

A case history has just been completed on an installation in a large, midwestern steel mill. As originally installed, fumes from the continuous pickling lines in the mill were removed through rubber-lined steel ducts. The ducts were installed under the pickling tanks to save space and to be out of the way of overhead traveling cranes.

The original system had corroded through and had been replaced once with a second rubber-lined steel duct system very similar to the first. This second system had also corroded through and was in need of replacement. Each of the two failures had been caused by dripping acid and high humidity underneath the pickling lines. The failures originated on the outside surface of the ducts; only the inside surfaces had been rubber lined. To rubber line the inside surfaces and rubber cover the outside surfaces of all the ducts would entail prohibitively high costs.

To meet the problem, the steel company's engineering and purchasing dept. determined to find ducts of a material that would give longer life and require little or no maintenance. Various plastic materials were considered including polyethylene and pvc. After extensive study and comparison, Heil Process Equipment Corp.'s Rigidon plastic duct (glass reinforced polyester) was selected because it was determined that the initial cost of the system would be substantially less than the cost of a rubber-lined steel duct system.

Furthermore, the material is lightweight, fire retardant and self-extinguishing and possesses sufficient strength to withstand normal mechanical abuse. The heat distortion point of the duct is 250 F and its thermal expansion, as would be expected, is less than that of rubber-lined steel duct.

The Rigidon duct can be repaired and existing duct work can be altered in the field. Cemented field joints can be easily made. Also the ducts can be shop fabricated to reduce installation costs, if desired.

Figure 1 — The scrubber handles a total of 112,000 cfm of acid fume-laden air.

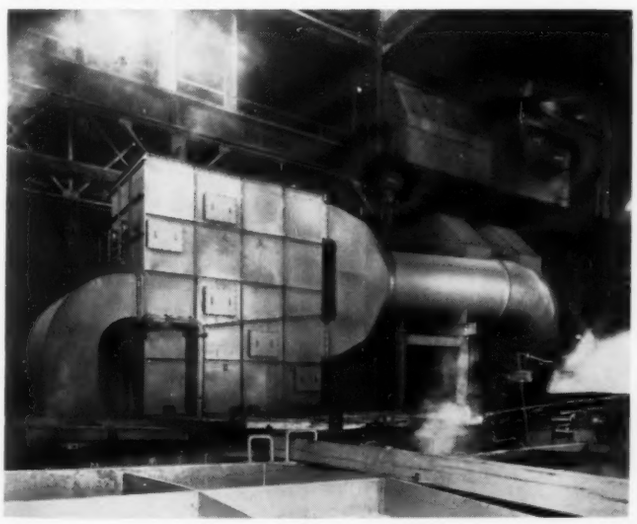
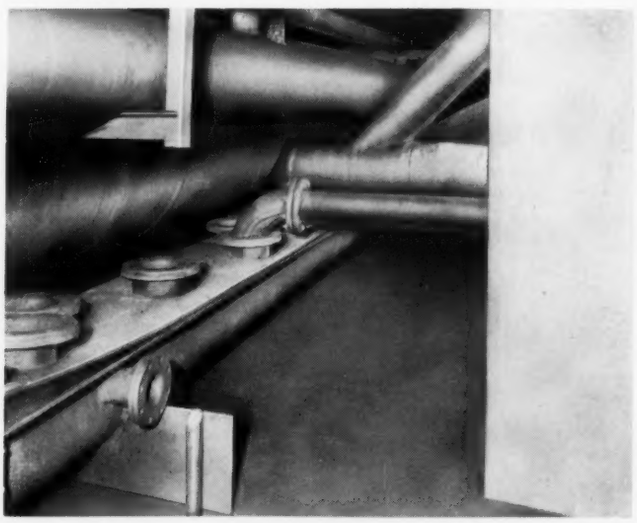


Figure 2 — The ducts are located beneath the pickling tanks to save space.



Moreoever, it is not necessary to paint the duct or protect the outside from dripping acid as the duct is a homogeneous structure and is acid resistant both inside and outside.

The fume removal system has been in service for more than 1½ years under the same conditions that caused two failures of the rubber-lined steel duct system. It has required no maintenance or repairs, and to all appearances is as serviceable now as the day it was installed.

FUME SCRUBBER

A 112,000-cfm fume scrubber to remove the sulphuric acid fumes before they are discharged to the atmosphere was also installed as part of the fume removal system. It was specially designed to fit between the pickling lines, and was built with a rubber-lined steel housing to withstand possible mechanical damage from the traveling crane.

Fumes from the continuous pickling lines, totaling 112,000 cfm are split into two streams and fed into the scrubber through two inlets. The high-efficiency scrubber is of the vertical counter-flow type (water flowing down and fumes flowing up). All the internals including the packing, spray piping and demisting unit are of solid plastic construction. The low pressure drop through the scrubber and low water consumption rates contribute to low operation costs. ▲

Very Thin Fused Coatings Deposited By Weld Surfacing

A NEW precision method for depositing fully-fused overlays of wear and corrosion-resistant alloys, plasmarc weld surfacing has been developed by Linde Co., Div. of Union Carbide Corp.

Linde's new process is the first developed that can deposit a very thin fused coating with controlled dilution at high speeds. The overlay metal or alloy is fed as a powder into the plasmarc torch. Intense heat is created by the constricted plasma arc, produced within the torch and transferred from the torch to the work. Argon gas, used to form the plasma, also shields the surfaced area from atmospheric contamination.

Plasmarc weld surfacing is a sister process to plasmarc cutting, which Linde introduced in 1955 for smooth-finish cutting of metals at speeds up to 300 in. per min.

Plasmarc weld surfacing equipment has the following features:

1. Penetration of the overlay into the base material can be held to a minimum of 0.005 in.

2. Dilution of the overlay with the base can be held to five per cent, or controlled up to 50 per cent.

3. Overlays as thin as 0.010 in. or as thick as $\frac{3}{16}$ in. can be produced in one pass, and any thickness can be achieved by using multiple passes.

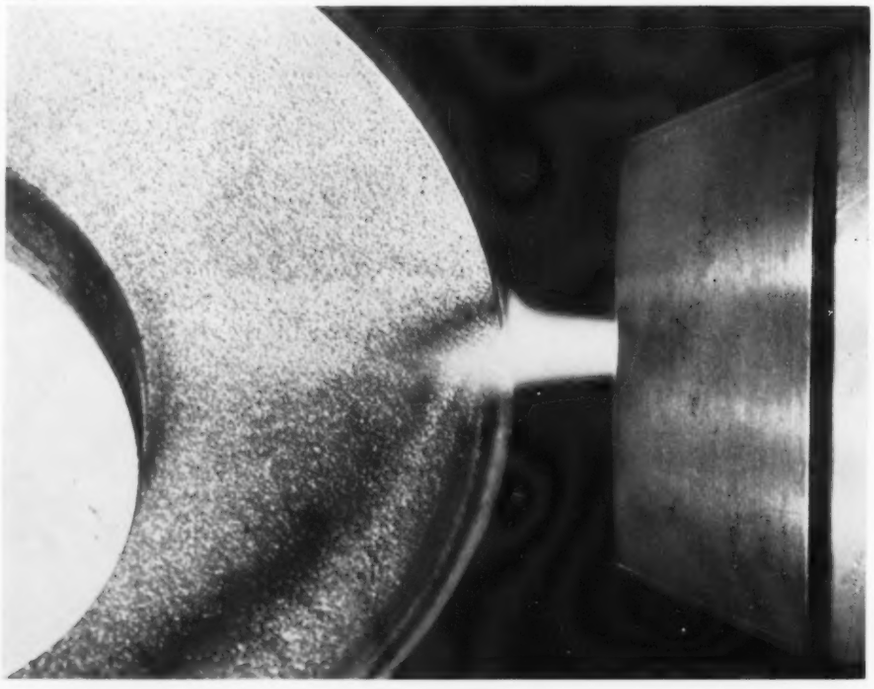
4. More than six lb of metal per hr can be deposited at an efficiency of 95 per cent.

5. Any metal or alloy which can be powdered and which is metallurgically compatible with the base metal (the melting point of the deposit must be comparable to or lower than that of the base metal) can be deposited.

6. A bead as narrow as $\frac{1}{8}$ in. or as wide as 1 in. or more (by oscillating the torch) can be made.

7. Flat, smooth deposits that require less finishing than other fusion processes are obtained. ▲

Figure 1 — Stellite is deposited on a 4-in. OD by ⅛-in. thick mild steel disk.



Investigate the new U.S. built

SCHLOEMANN

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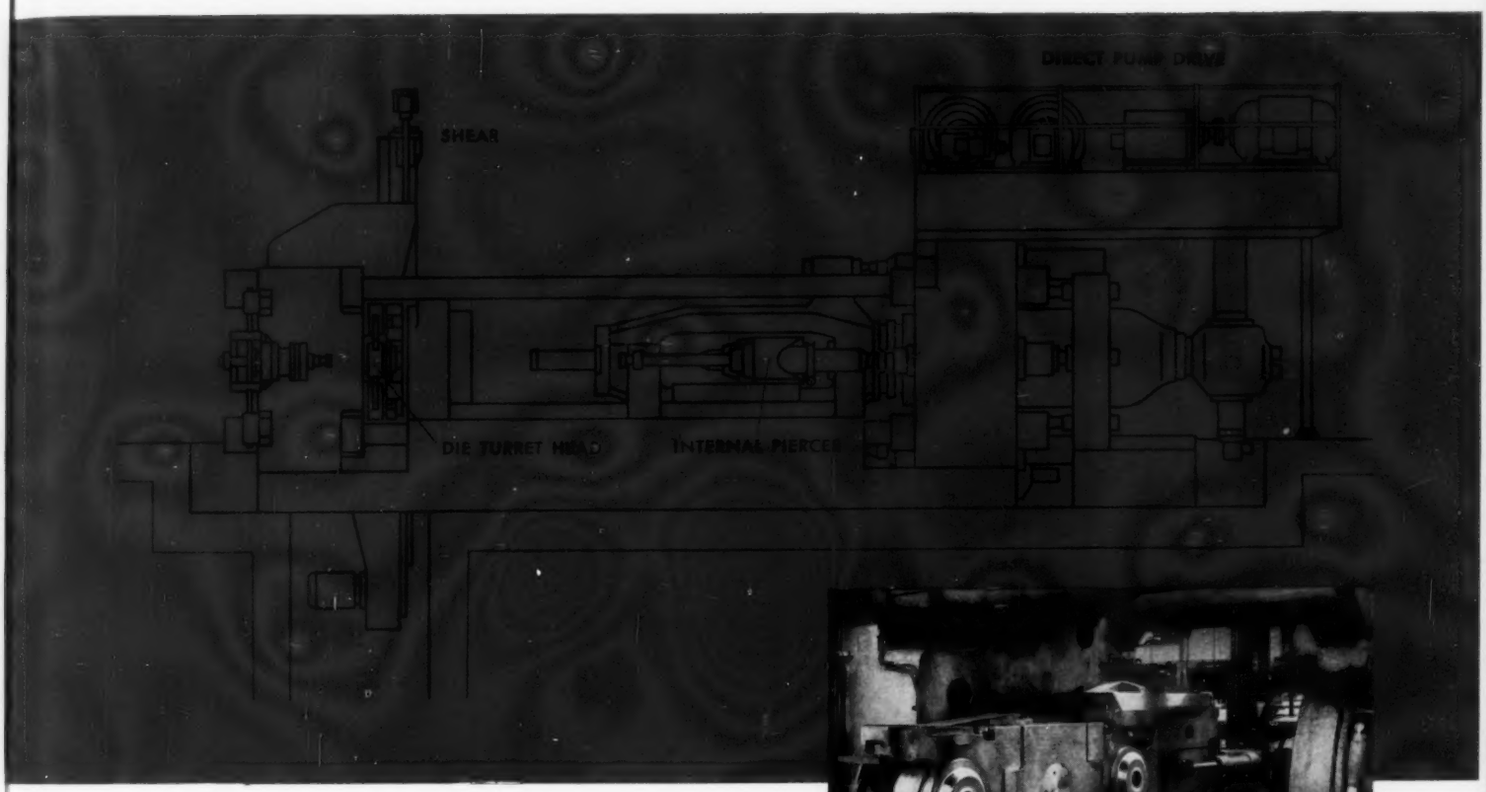
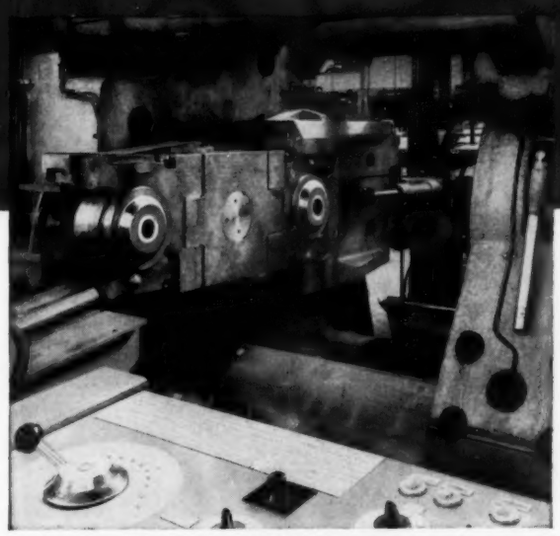




Die turret head of a new SCHLOEMANN press in Europe

Automatic rod and tube self contained extrusion press

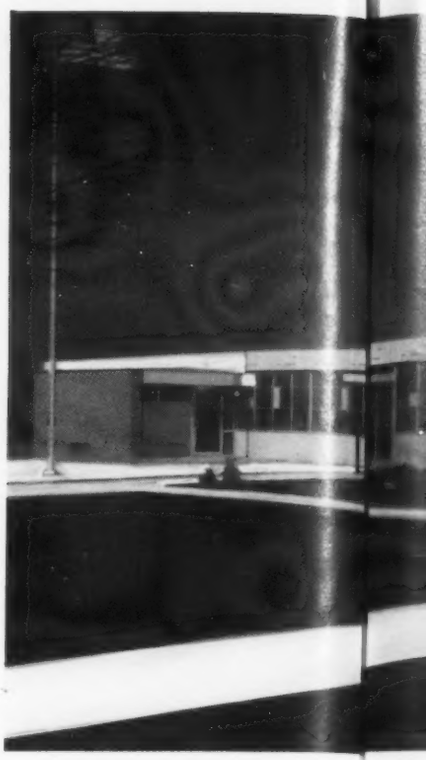
This press is designed for high productivity, gauge accuracy and minimum cycle time. SCHLOEMANN know-how based on many years of experience is incorporated in the new press. Such additional features as "static" controls for press and auxiliaries render electrics simpler and more effective. This together with the direct pump drive allows for efficient production at high or low press speeds.

To date thirty-five of these new presses up to 5500 tons capacity have been built or are on order. Consult us on further details of the new U. S. built SCHLOEMANN press.

- Multiple die holder turret head
- Severing in front or behind die
- Internal piercer
- Fully automatic working cycle

FELLER ENGINEERING COMPANY 1161 Empire Building, Pittsburgh 22, Pa.

ROLLING MILLS FOR FERROUS AND NON-FERROUS METALS • COUNTERBLOW HAMMERS • HYDRAULIC PRESSES



Electrical Protection goes MODERN with BUSS Fuses...

in All-Electric Schools

Utica Michigan

• *Electricity* heats, lights, pumps water, cooks and operates all motor driven equipment in the West Utica and the Ewell Elementary Schools. No other utility service is used except the telephone.

The complete use of electrical energy puts special emphasis on the need to use the safest, most modern protective devices throughout the electrical system.

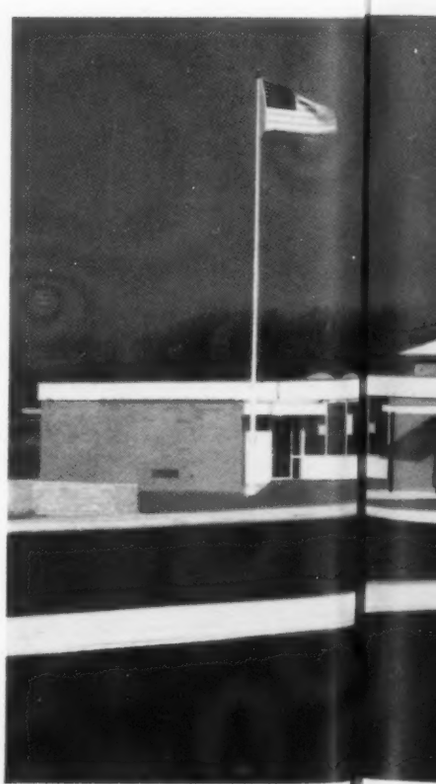
In each school, the main switchboard is protected by 3—1600 ampere BUSS Hi-Cap fuses having an interrupting rating of 200,000 amps. rms symmetrical. Thus, safe interruption of fault currents now available is assured,—and the fuses are adequately safe to allow for future system growth.

If a high fault current should occur, the fast opening characteristics of BUSS Hi-Cap fuses further protect the circuits and equipment against damage by restricting let-thru fault currents to safe value.

Feeder and branch circuit protection

To provide the safest short-circuit and overload protection . . . and to prevent needless outages,—FUSETRON dual-element fuses are used in the feeders and branch circuits of these schools.

For modern, all-purpose protection of circuits up to 600 amps., FUSETRON fuses cannot be equalled. They have 100,000 amp. interrupting capacity,—and sufficient time-lag to hold harmless overloads.

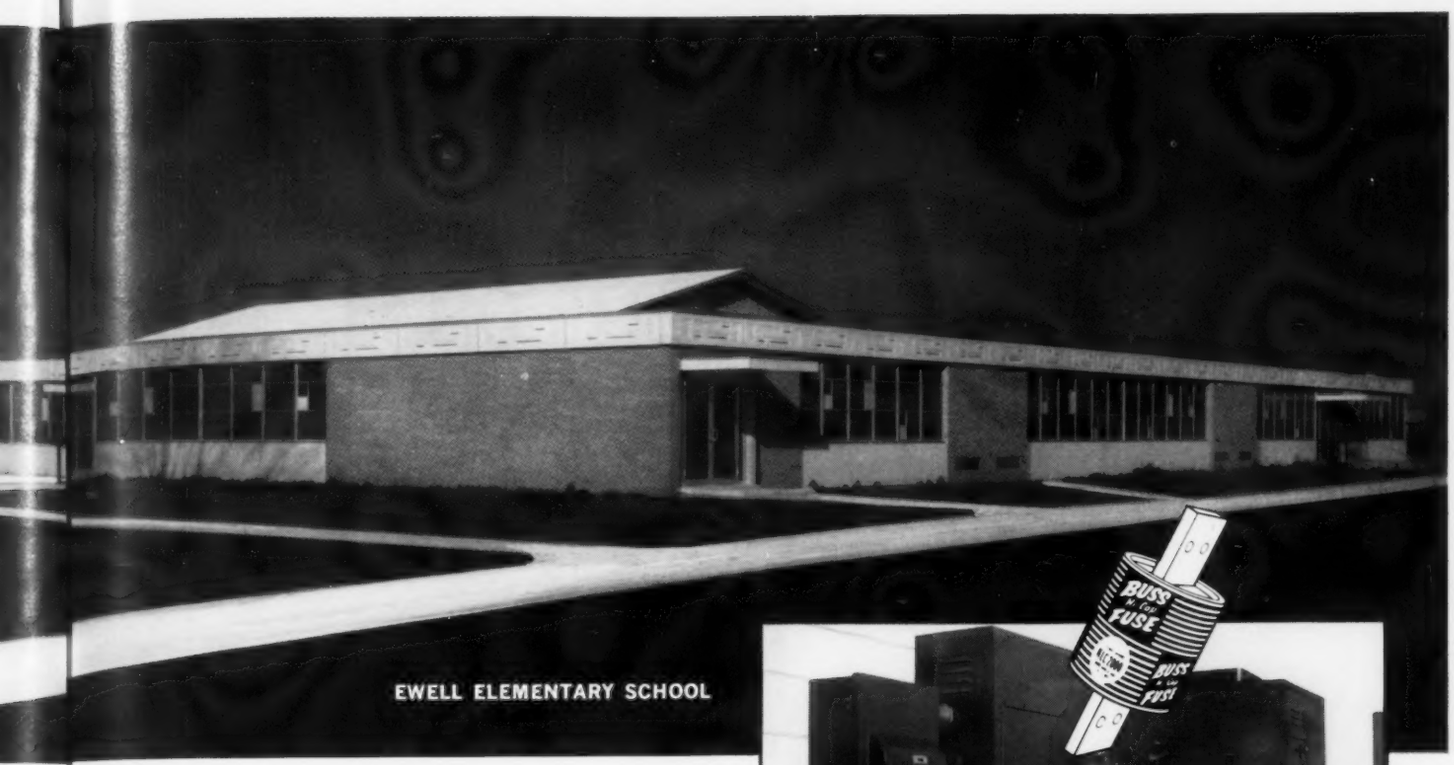


For more information on

FUSETRON dual-element fuses *. . . write for bulletin FIS*

BUSS Hi-Cap fuses *. . . write for bulletin HCS*

BUSSMANN MFG. DIVISION, *McGraw-Edison Co.* **St. Louis 7, Mo.**



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Switchboards protected by BUSS Hi-Cap and FUSETRON dual-element fuses.

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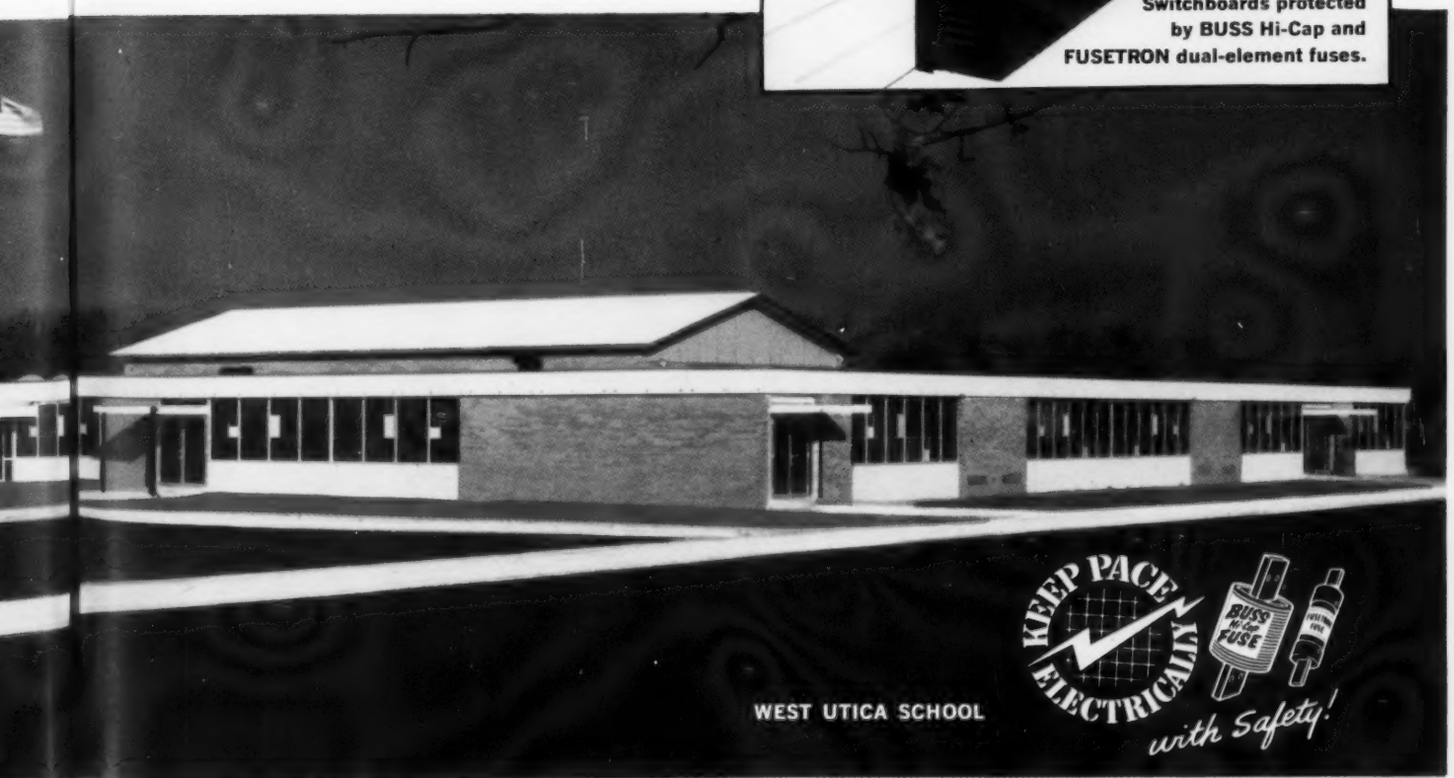

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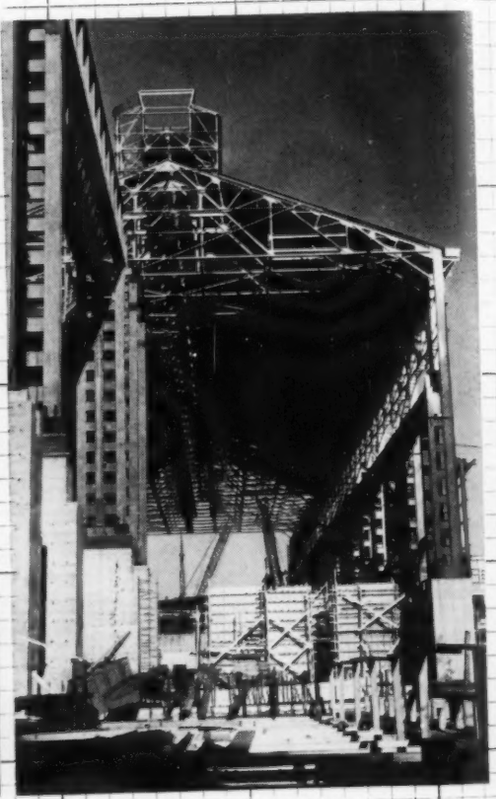

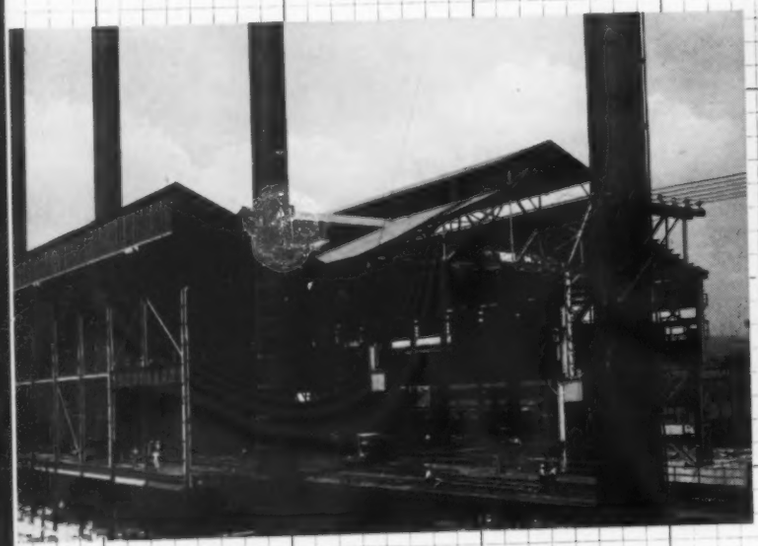

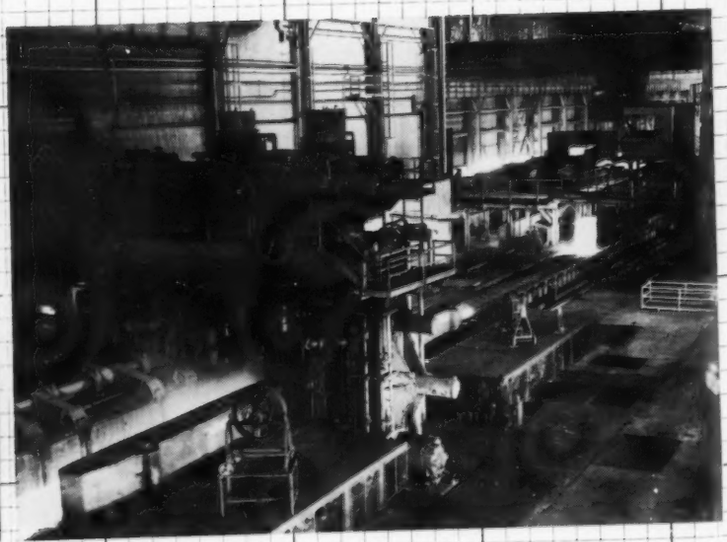

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SWINDELL-DRESSLER engineering covers the range of steelmaking requirements from feasibility studies to complete plants and owners' key. Integrated steel mills, basic oxygen steel plants, electric steel melt shops, gas cleaning systems, departmental expansion or remodernization are among the many areas served by this long-experienced metals engineering organization.

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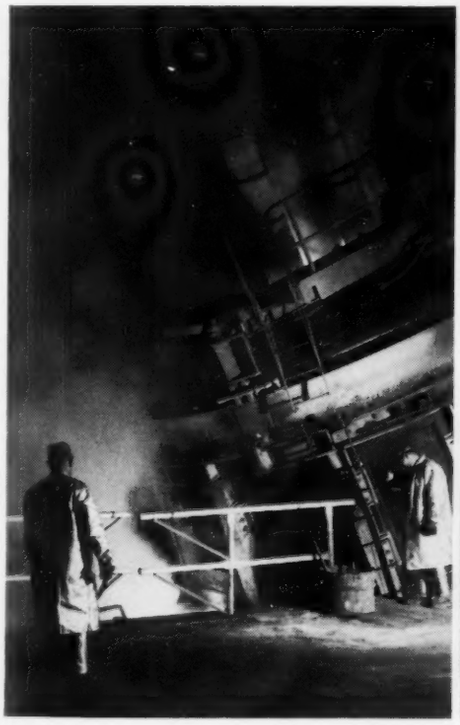

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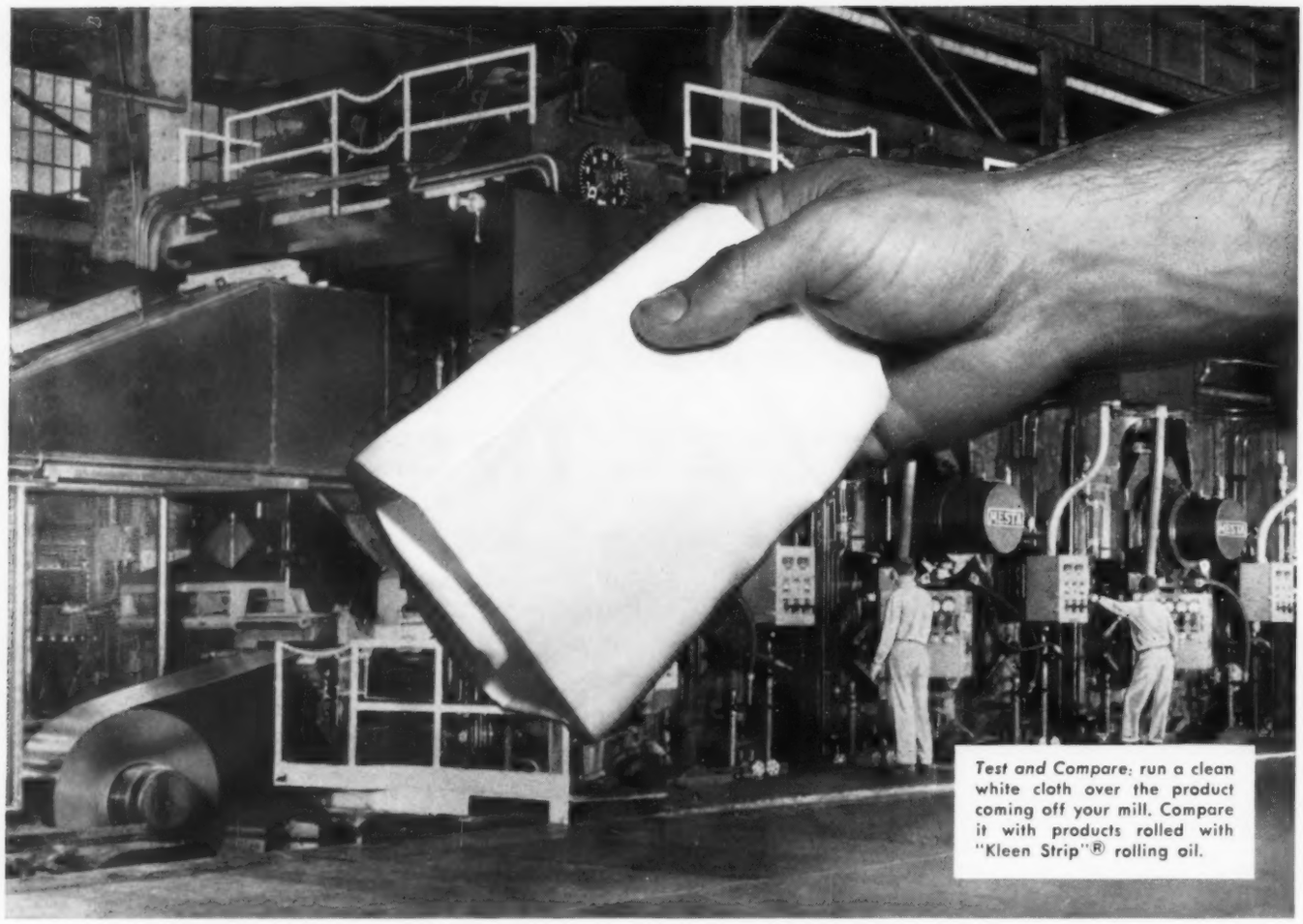

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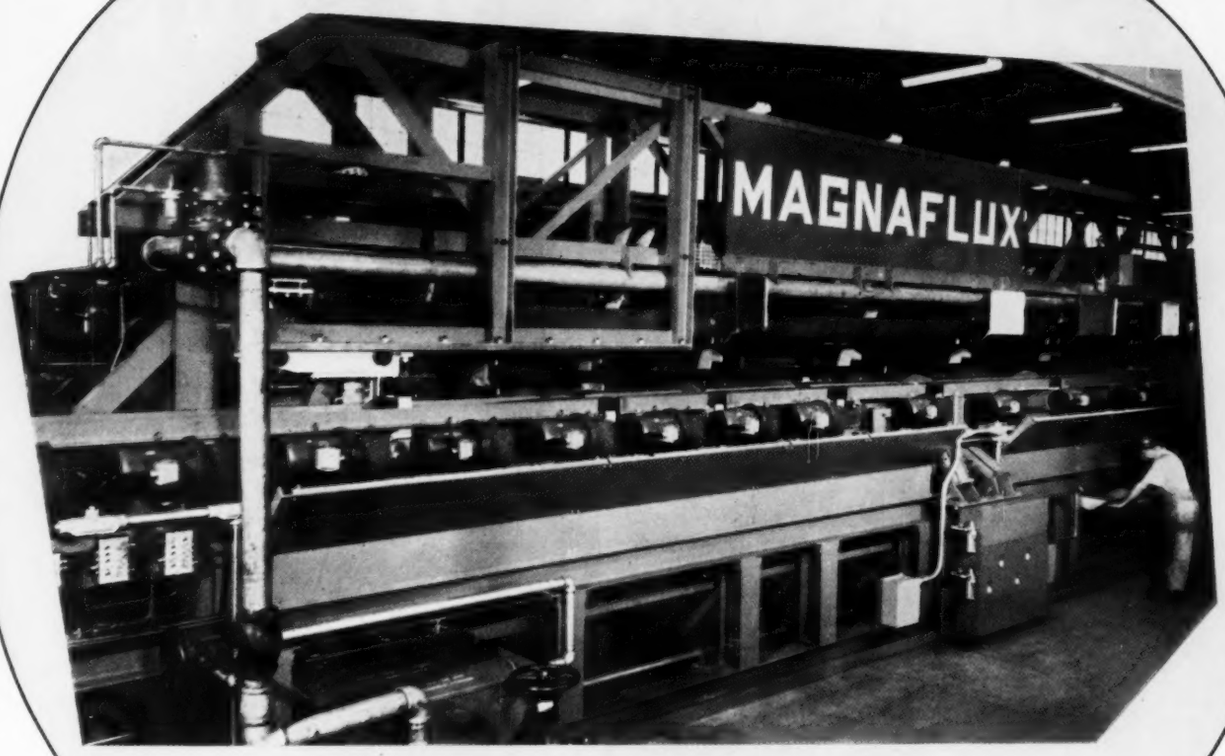
There's a RAMTITE® Product for every Refractory User!

Another Test System at work...



Push-button actuation conveys billets into test unit, transfers them to magnetization and Magnaglo bath station and on to black light viewing area. A novel device rotates them so operators see all four sides. As one billet leaves, another is ready for viewing; testing is nearly continuous.

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Date-line Diary...

September 1

Δ The Bureau of the Census reports that shipments of iron and steel castings for June, 1961, totaled 1,203,569 net tons compared with 1,155,930 tons in May, 1961 and 1,259,223 tons in June, 1960.

Δ The Bureau of Mines reported that production of pig iron in the U. S. in May, 1961, totaled 5,646,390 net tons; U. S. production of steel ingots and castings in May, 1961, totaled 9,072,719 tons.

Δ The American Iron Ore Assn. reports that U. S. shipments of iron ore down the Great Lakes in August, 1961, totaled 9,196,182 gross tons, compared with 9,358,040 tons in August, 1960.

Δ New York Federal Reserve Bank disclosed that the U. S. gold stocks totaled $17,452,000,000, down $150,000,000 in the last week.

September 2

Δ The AISI reports that production of steel for the week ending September 2, 1961, totaled 2,030,000 net tons (about 71.3 per cent of capacity) compared with 2,020,000 tons one week ago (70.7 per cent of capacity) and 1,483,000 tons one year ago. Index of production was 109.0.

September 5

Δ The Federal Reserve Board reported that consumer credit in July, 1961, declined $74,000,000, compared with expansion to $100,000,000 in June, 1961.

Δ Walter Heller, chairman of the President's Council of Economic Advisers predicted that gross national product may rise to an annual rate of $570,000,000,000 by the second quarter of 1962 and reported that it may take a year or two before the unemployment rate falls to four per cent from the current rate of just below seven per cent.

Δ The Bureau of Mines reports that production of Pennsylvania anthracite for August, 1961, totaled 1,535,000 net tons, compared with 1,202,000 tons in July, 1961, and 1,704,000 tons in August, 1960.

September 6

Δ A study released by the President's Council of Economic Advisers indicated that steel producers can earn at a yearly rate of 7 to 15 per cent, after taxes, on the asset value of their outstanding shares for the fourth quarter, 1961, without increasing prices. Rising output was cited as more than offsetting wage increases scheduled for October 1, 1961.

Δ The Dept. of Commerce reported that inventories of manufacturers, wholesalers and retailers rose to a seasonally adjusted $91,800,000,000 in July, 1961, an increase of $300,000,000 from the June, 1961, level. Total sales in July, 1961 to a seasonally adjusted $61,600,000,000, down $300,000,000 from June, 1961.

September 7

Δ The AISI reports that the steel industry's payroll for hourly and salaried workers in July, 1961, totaled $307,047,803 compared with $321,075,715 in June, 1961. Total employed in July numbered 538,383 compared with 532,282 in June. Payroll cost per hr worked by hourly employees was $3.520 in July compared with $3.480 in June not including 50¢ per hr supplemental employee benefits. Average hours worked per week were 33.2 in July, 1961, compared with 37.5 in June, 1961.

September 8

Δ The Census Bureau reported that U. S. imports in July, 1961, rose to a seasonally adjusted $1,371,400,000, up 16 per cent over June, 1961, and nine per cent over July, 1960.

September 9

Δ The AISI reported that steel production for the week ending September 9, 1961, totaled 2,032,000 net tons (about 71.4 per cent of capacity) compared with 2,030,000 tons one week ago (71.3 per cent of capacity) and 1,401,000 tons one year ago. Index of production was 109.1.

Δ The Bureau of Mines reports that U. S. consumption of scrap in July, 1961, totaled 4,295,000 gross tons, compared with 4,937,183 tons in June, 1961; pig iron consumption in July, 1961, totaled 5,025,000 tons, compared with 5,242,156 tons in June, 1961.

Δ The Bureau of the Census reported that shipments of commercial steel forgings in July, 1961, totaled 72,291 short tons compared with 107,597 tons in June, 1961 and 79,169 tons in July 1960. Unfilled orders on July 31, 1961, amounted to 282,495 net tons, compared with 258,690 tons on June 30, 1961, and 293,419 tons on July 31, 1960.

September 12

Δ The Commerce Dept. reported that retail sales in August, 1961, totaled $18,100,000,000 after seasonal adjustment, up $47,000,000,000 from the July volume, and compared with $18,200,000,000 in August, 1960.

Δ The AISI announced that shipments of finished steel products in July, 1961, totaled 5,120,808 net tons, compared with 6,133,519 tons in June, 1961, and 4,710,565 tons in July, 1960.

September 13

Δ The Labor Dept. reported that unemployment in mid-August totaled 4,500,000, a decrease of 598,000 from mid-July; employment in mid-August was reported to total 68,500,000.

Δ The AISI reported that U. S. steelmaking furnaces in August, 1961, poured 8,657,000 net tons of ingots and steel for castings, compared with 8,091,958 tons in July, 1961, and 6,838,000 tons in August, 1960.

September 14

Δ Ford Motor Co. plans to buy Philco Corp. under an agreement exchanging one share of Ford common for each 4½ shares of Philco common. Philco preferred will be exchanged for Ford common approximately $101.50 for each share, plus accrued dividends.

Δ U. S. Steel advised President Kennedy he cannot expect industry to hold its prices stable in the face of mounting costs without endangering national growth and left itself open to boost steel prices later this year if it thinks price increases are needed.

September 15

Δ The Federal Reserve Board reported that industrial production in August, 1961, reached 113 per cent of the 1957 average, up from 112 per cent in July, 1961.

Δ Lone Star Steel Co. filed a suit against the AFL-CIO United Steelworkers of America in Federal District Court, Dallas, Texas, for $5,500,000 losses alleged to have resulted from a wildcat strike at the company's main plant in 1957.

△ The Aluminum Assn. reported that net shipments of aluminum sheet and plate in July, 1961, totaled 121,016,000 lb, compared with 133,951,000 lb in June, 1961, and 121,215,000 lb in July, 1960. Shipments of aluminum foil in July, 1961, totaled 17,777,952 lb in July, 1961, compared with 21,098,094 lb in June, 1961, and 17,805,391 lb in July, 1960.

September 16

△ The AISI reported that steel production for the week ending September 16, 1961, totaled 2,032,000 net tons (about 71.4 per cent of capacity) compared with 2,032,000 tons one week ago (71.4 per cent of capacity) and 1,510,000 tons one year ago. Index of production was 109.1.

September 19

△ The Bureau of the Census reported that shipments of titanium mill products in July, 1961, totaled 727,937 lb, compared with 708,626 lb in June, 1961, and 606,238 lb in July, 1960.

△ The Bureau of the Census reported that net shipments of aluminum pig and ingots in July, 1961, totaled 110,774,000 lb, compared with 118,819,000 lb in June, 1961, and 102,425,000 lb in July, 1961; net shipments of aluminum mill products in July, 1961, totaled 263,567,000 lb, compared with 304,334,000 lb in June, 1961, and 253,070,000 lb in July, 1960. Shipments of magnesium mill products in July, 1961, totaled 1,743,000 lb, compared with 1,700,000 lb in June, 1961, and 1,510,000 lb in July, 1960.

September 20

△ The ARCI reported that deliveries of new freight cars in August, 1961, totaled 2428 compared with 1229 in July, 1961, and 4124 in August, 1960. Orders in August, 1961, totaled 1474, compared with 2452 in July, 1961, and 1343 in August, 1960. Backlog of cars on order as of September 1, 1961, totaled 9690, compared with 10,644 on August 1, 1961, and 23,866 on order on September 1, 1960.

△ The Aluminum Assn. reported that production of primary aluminum in the U. S. in August, 1961, totaled 167,040 net tons, compared with 164,733 tons in July, 1961, and 172,973 tons in August, 1960.

△ Commerce Secretary Hodges said that the nation's output of goods and services is at an annual rate of, $526,000,000,000 in the current quarter compared with the second quarter rate of $516,000,000,000.

September 22

△ Woodward Iron Co. holders of common stock will vote on a proposed 625,000-share increase in authorized common stock, to pave the way for acquisition of Lynchburg Foundry Co., Lynchburg, Va., and National Cement Co., Ragland, Ala.

September 23

△ The AISI reported that steel production for the week ending Sept. 23, 1961, totaled 2,114,000 net tons, (about 74.1 per cent of capacity) compared with 2,032,000 tons one week ago (71.4 per cent of capacity) and 1,547,000 tons one year ago. Index of production was 113.5.

September 25

△ Northwestern Steel and Wire Co. reports for the year ending July 31, 1961, net sales totaling $79,612,972, net earnings of $7,041,816, equal to $2.81 per share, compared with 1960 net sales totaling $67,258,342, net earnings of $5,873,265, equal to $2.35 per share.

△ Aluminum Corp. of America, Kaiser Aluminum & Chemical Corp. and Reynolds Metals announced a new domestic price for aluminum ingots of 24¢, down 2¢ per lb.

△ The Bureau of Mines reports that production of pig iron in the United States in June, 1961, totaled 5,687,134 net tons, steel ingots and castings produced in June, 1961, totaled 8,645,216 tons.

September 26

△ The National Machine Tool Builders Assn. reports that net new orders of cutting and forming-type machine tools in August, 1961, amounted to $56,000,000, compared with $55,650,000 in July, 1961. Shipments of cutting and forming-type tools in August, 1961, amounted to $47,950,000 compared with $49,750,000 in July, 1961.

△ The AISC reported that bookings of fabricated structural steel in August, 1961, totaled 384,981 tons, compared with 456,332 tons in July, 1961, and 292,960 tons in August, 1960. Shipments in August, 1961, totaled 359,467 tons, compared with 286,917 tons in July, 1961, and 373,374 tons in August, 1960. Backlog as of August 31, 1961, amounted to 2,377,514 tons.

September 27

△ The Bureau of the Census reports that shipments of nonferrous castings in July, 1961, totaled 134,566,000 lb, compared with 180,304,000 lb in June, 1961.

September 28

△ Union Carbide Metals Co., Div. of Union Carbide Corp., announced an average price increase of less than 2¢ a lb of chromium on ferrochrome alloys.

△ At a special meeting Pittsburgh Steel Co. stockholders voted approval of: (1) increasing authorized shares of common stock of the company from 2,500,000 to 4,000,000 shares; (2) changing par value of common stock from $10 per share to common stock without par value; and (3) instituting a new stock option plan for officers and certain key employees.

September 29

△ Weirton Steel Co. announced that production and maintenance employees will receive a wage increase ranging from 7 to 10¢ an hr on October 1, under terms of labor agreement between the company and the ISU which runs to June 30, 1962.

△ American Iron Ore Assn. and AISI jointly report that receipts of iron ore and iron ore agglomerates in the U. S. in August, 1961, totaled 13,483,430 gross tons, compared with 13,894,101 tons in August, 1960. Consumption in August, 1961, totaled 8,767,096 tons, compared with 6,728,535 tons in August, 1960. Of the existing 255 blast furnaces, 150 were operating on August 31, 1961, compared with 129 on August 31, 1960.

△ F. W. Dodge Corp. reported that total construction contracts in August, 1961, amounted to $3,542,567,000, compared with $3,295,217,000 in August, 1960. Index (1947–49 = 100) in August, 1961, was 293, compared with 277 in July, 1961, and 276 in August, 1960.

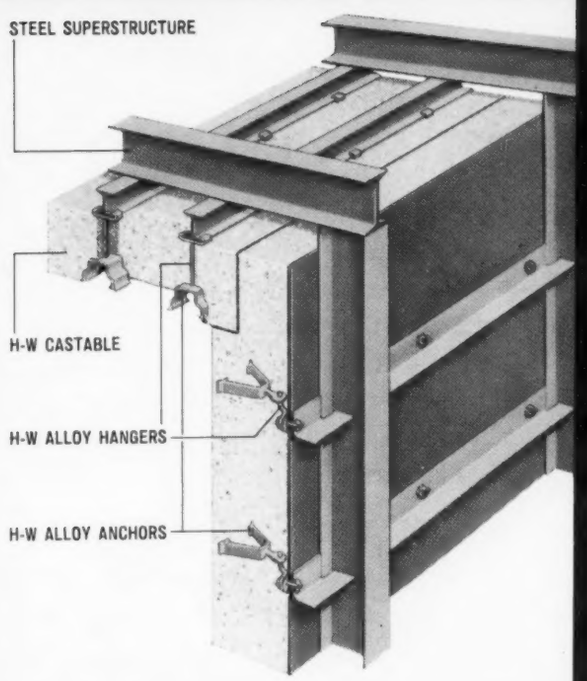
September 30

△ Steel industry wage increases estimated at 13¢ per hr will go into effect October 1, 1961, for 500,000 steelworkers.

△ Spot copper closed in London at 27 7/8¢ per lb, down 1/2¢ from the preceding week.

△ Bureau of the Census reported shipments of iron and steel castings in July, 1961, totaled 923,152 net tons, compared with 1,203,569 tons in June, 1961, and 942,731 tons in July, 1960.

△ The AISI reports that production of steel for the week ending September 30, 1961, totaled 2,131,000 net tons (about 74.8 per cent of capacity) compared with 2,114,000 tons one week ago (74.1 per cent of capacity) and 1,558,000 tons one year ago. Index of production was 114.4.



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CASTABLE FURNACE LININGS

The speed and ease with which refractory linings can be installed with Harbison-Walker castable refractories have resulted in savings of thousands of dollars in furnace construction. H-W castables have excellent dimensional stability, have low permeability and thermal conductivity, and are resistant to spalling and abrasion.

Harbison-Walker has available a *complete* range of castables—from very light insulation to heavy slag-and-abrasion-resistant types—to meet virtually any service requirement.

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SAVE TIME AND MONEY

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Getting the optimum service life from monolithic structures more often than not depends on proper anchoring or reinforcement. Harbison-Walker has developed a whole series of high temperature metal and refractory anchoring systems to assure proper castable construction. *Complete* technical service is available. Write for details.

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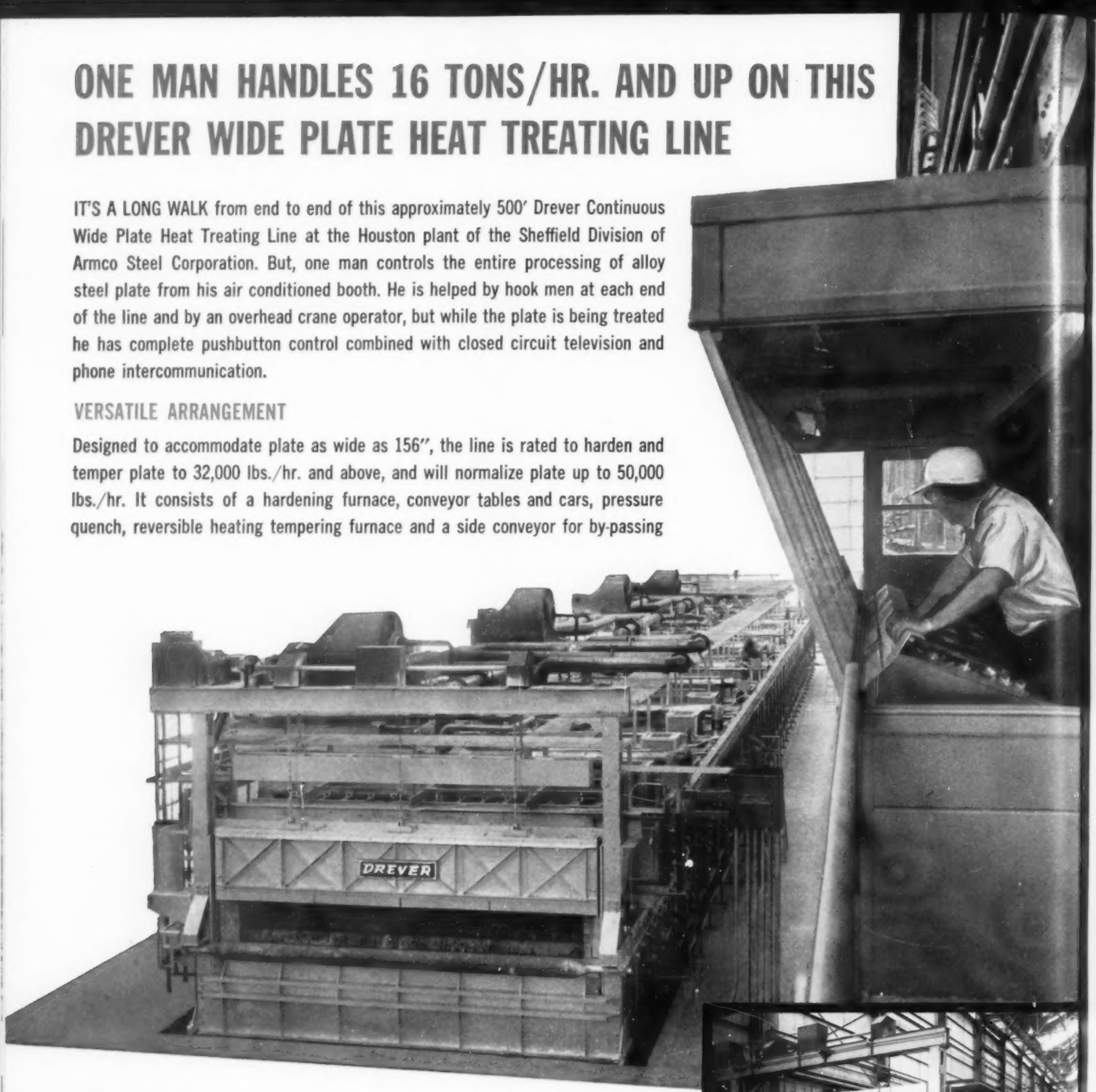
HW-61-17

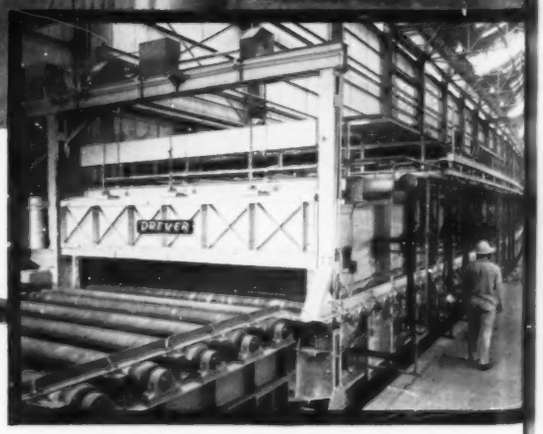
ONE MAN HANDLES 16 TONS/HR. AND UP ON THIS DREVER WIDE PLATE HEAT TREATING LINE

IT'S A LONG WALK from end to end of this approximately 500′ Drever Continuous Wide Plate Heat Treating Line at the Houston plant of the Sheffield Division of Armco Steel Corporation. But, one man controls the entire processing of alloy steel plate from his air conditioned booth. He is helped by hook men at each end of the line and by an overhead crane operator, but while the plate is being treated he has complete pushbutton control combined with closed circuit television and phone intercommunication.

VERSATILE ARRANGEMENT

Designed to accommodate plate as wide as 156″, the line is rated to harden and temper plate to 32,000 lbs./hr. and above, and will normalize plate up to 50,000 lbs./hr. It consists of a hardening furnace, conveyor tables and cars, pressure quench, reversible heating tempering furnace and a side conveyor for by-passing the tempering furnace or for repassing the plate through the tempering unit. This is the second Drever Heat Treating Line at the Sheffield plant.





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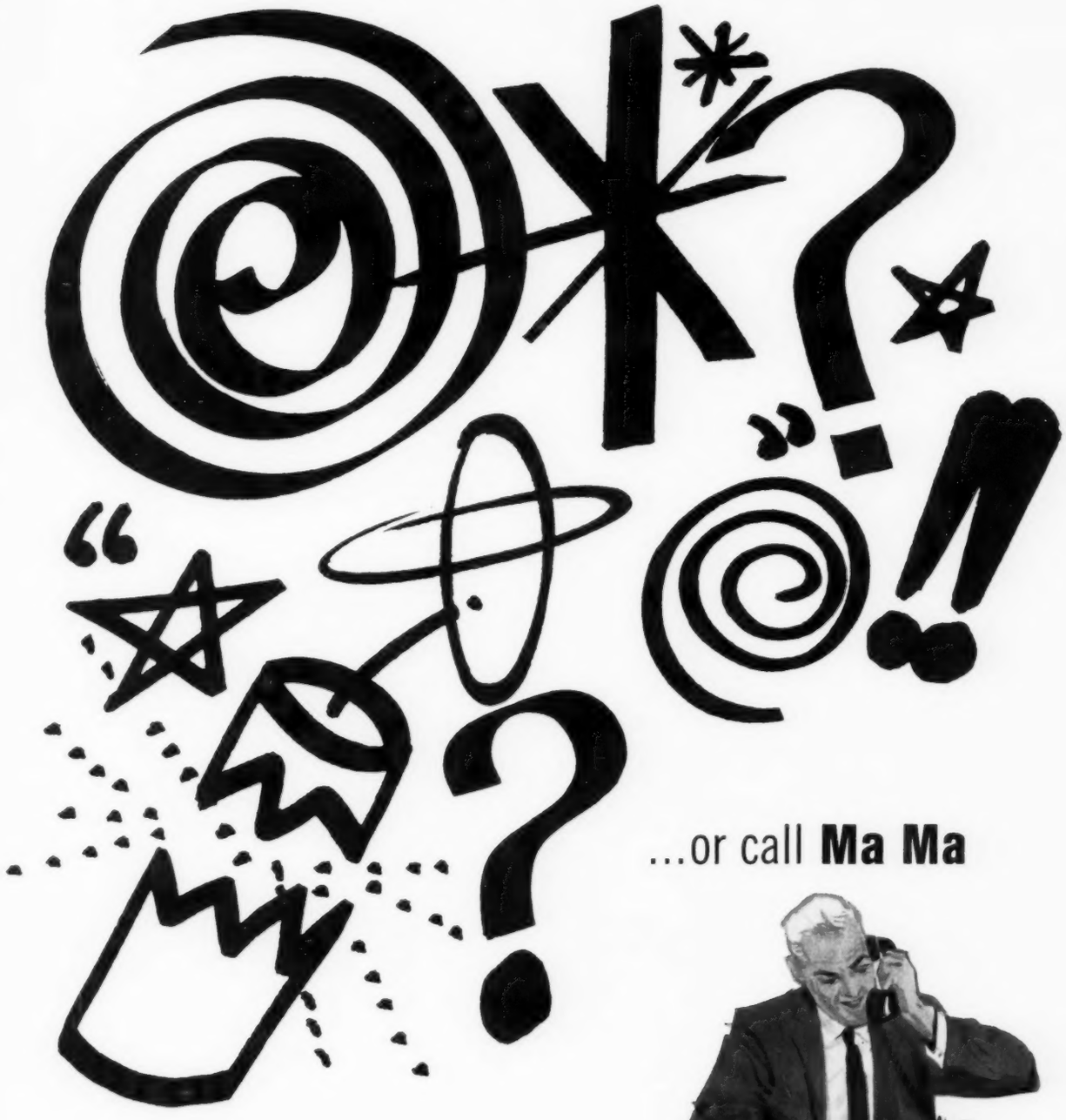

...or call **Ma Ma**

IF A MAN ANSWERS . . . start talking. Talk about your mother-in-law. Your children's braces. Fido's scrofula. Discuss your golf game. Ask why your wife and secretary don't understand you. Then, tell him about your replacement parts problem. Because that's what he can **really** help you with. He's an expert on **any replacement problem related to Mill-Type equipment** ■ Ma Ma wants to bid, from your specifications, on your next equipment need. Ma Ma delivers fast. And spends your money well. Call Ma Ma! Ma Ma is an easy name to remember. It stands for MAchinery-MAintenance Division, Coronado Steel Company. MA MA's phone number is 747-4436.

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How NBD product engineering produces better screw nuts

A report on centrifugally cast screw nuts and a new proof-ring inspection method

What makes a good screw-down nut? How long should it last? What causes early failure? When NBD product engineers were assigned the job of producing superior screw-down nuts, they asked these questions of blooming and slabbing mill operators. Answers varied greatly. "Good" life in one mill might be 1,000,000 tons of steel rolled. In another, life might be 4,000,000 tons — because of the peculiar operating characteristics of the mill. All agreed, however, that NBD's greatest contribution would be: (1) Production of screw nuts having maximum physical properties within the limits of the bronze alloy specified, and (2) absolutely sound castings, particularly in the critical threaded areas of the nut.

Evaluation method

Because of the recognized superiority of centrifugal castings for most applicable bronze designs, this method of manufacture seemed the logical approach to attain the desired screw-nut characteristics. Questions were

r sed, however, in connection with t e heavy metal sections of screw n ts, often exceeding 6″. Would the n ss effect of these heavy sections p omote shrinkage or massive grain g owth which would adversely affect t nsile properties?

To resolve the questions, NBD product engineers made comparative tests on two 6,000-pound nuts, poured under identical controlled conditions from the same heat of NBD Alloy 65 N. (87½% Cu—11% Sn—1½% Ni). One was cast centrifugally. The other was cast in a chilled static mold.

Duplicate test sections were then cut from each casting, diametrically opposite each other, from several locations in the nuts.

TENSILE TEST RESULTS

Test Location	Tensile Strength, PSI		Yield Strength, PSI		% Elongation—2″	
	Centrifugal	Static	Centrifugal	Static	Centrifugal	Static
A	54,800	52,800	26,700	23,700	37.0	31.25
B	53,325	52,200	26,850	23,950	30.25	34.5
C	51,800	46,600	26,750	23,900	22.0	23.0
AVERAGE	53,308	50,533	26,767	23,850	29.75	29.58

HARDNESS READINGS

Hardness readings were also made on slices cut from the nuts, near the top, center and bottom. These readings, taken at 1″ intervals from the O. D. to the I. D. were as follows:

BHN Hardness—500 kg Load

	O. D.	1″	2″	3″	4″	5″	6″	I. D.	Average
Centrifugal	98.5	99.0	94.5	96.5	98.0	99.5	95.0	97.0	97.25
Static	100.0	99.0	97.0	96.0	92.5	87.0	88.0	90.5	93.75

Micro and Macro Studies

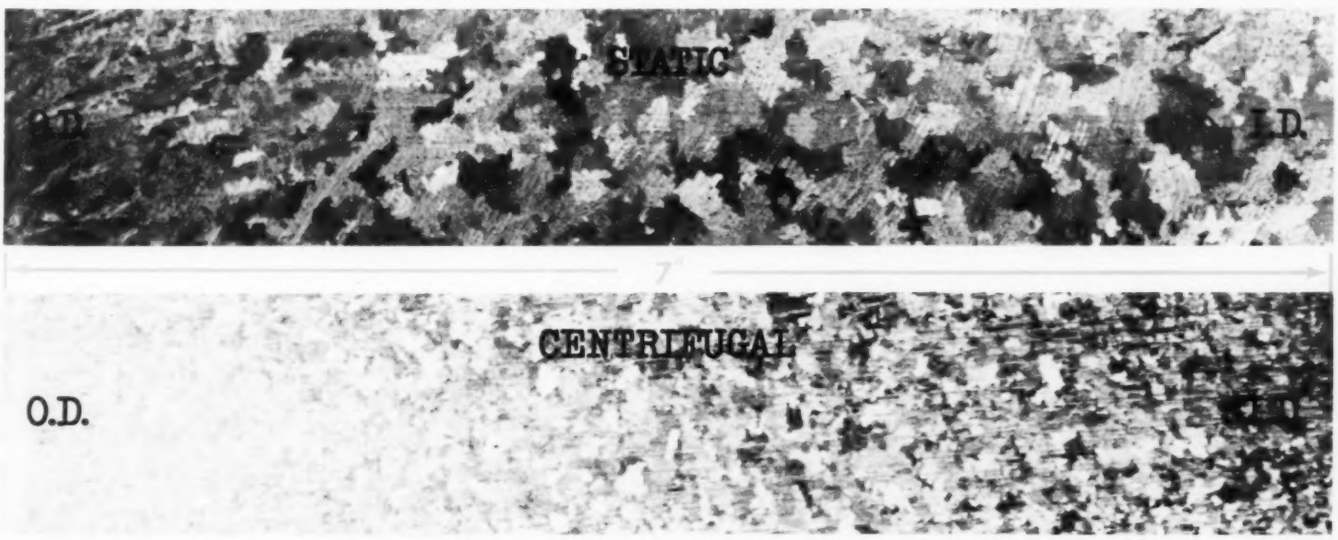
Micro and macro studies further strengthened the case for centrifugal castings, particularly in the critical I. D. of the screw nut. Note the pronounced finer grain in the centrifugal macrophotograph.

Proof-ring assures 100% quality

While the foregoing tests proved the superiority of the centrifugally cast nut — one big question remained: How could NBD customers be absolutely positive that every screw nut purchased was dense, sound and strong in the important threaded area? Visual inspection was not the answer. Dye-check, used extensively by NBD, was only partially effective. X-Ray was not practical because of the heavy metal sections involved.

From this enigma came a unique solution: a proof-ring which *exactly* duplicates the quality of the thread area of the casting. Without damaging the nut in any way, the proof-ring may be chemically analyzed, fractured, studied microscopically or otherwise tested. The proof-ring can be shipped to customers for evaluation — enabling them to inspect the nut quality — prior to its shipment.

The NBD sales engineer is prepared to give you more details on this proof-ring testing method. For further details on this unique proof-ring inspection technique, contact an NBD sales engineer, or write us.



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DESIGNERS AND BUILDERS OF ELECTRIC OVERHEAD TRAVELING CRANES AND HOISTS AND ELECTRIC REVOLVING CRANES

HERC-ALLOY

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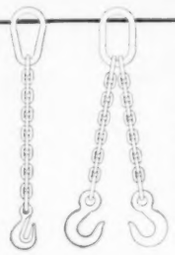

● Has many superior features—is lighter, therefore easier to handle...is long wearing...has high resistance to impact loading...is Inswell welded. Chain and all fittings are 125,000 p.s.i. tensile strength alloy steel.

● Write for Bulletin 100 covering Herc-Alloy Sling Chains, including helpful information on their care, use and inspection.

● Sold in running lengths, slings assembled to customers' specifications and other special assemblies.

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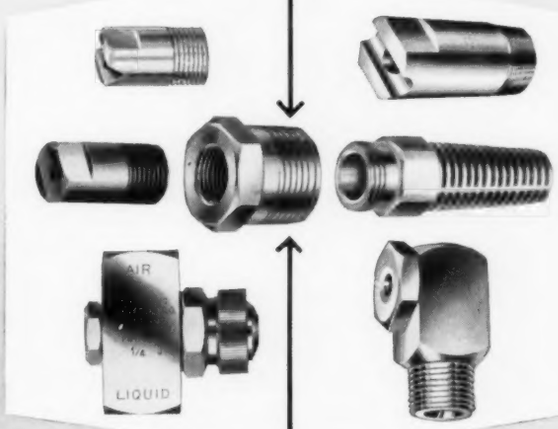
Whatever the application you will find Spraying Systems Spray Nozzles provide noticeable improvement in spraying operations . . and often materially lower cost. Proved by performance. Supplied in a complete choice of types and capacities for selection of spray characteristics exactly as needed. Your inquiry is cordially invited.



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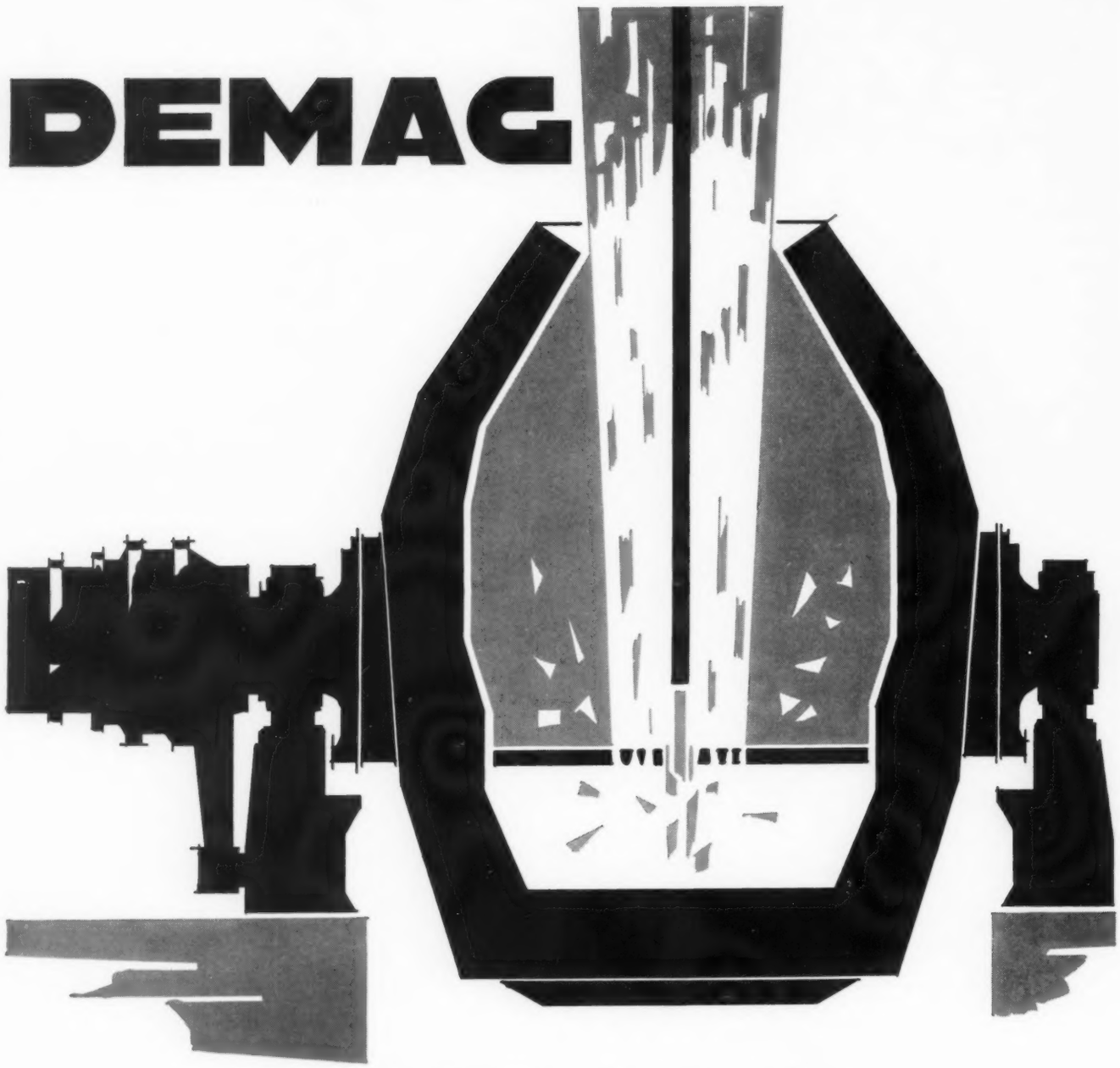
DEMAG



Milestones in Oxygen Steelmaking LD

The LD-Process started a revolution in steelmaking. DEMAG has played a leading part in this development, including the building of 5 to 175 metric ton LD furnaces and the design of super LD furnaces from 250 to 300 tons. Further new developments typical of DEMAG's work in oxygen steelmaking include:

LD-AC Furnaces • Rotor Furnaces • Kaldo Furnaces

AMERICAN DEMAG CORPORATION, ONE GATEWAY CENTER, PITTSBURGH 22, PA.

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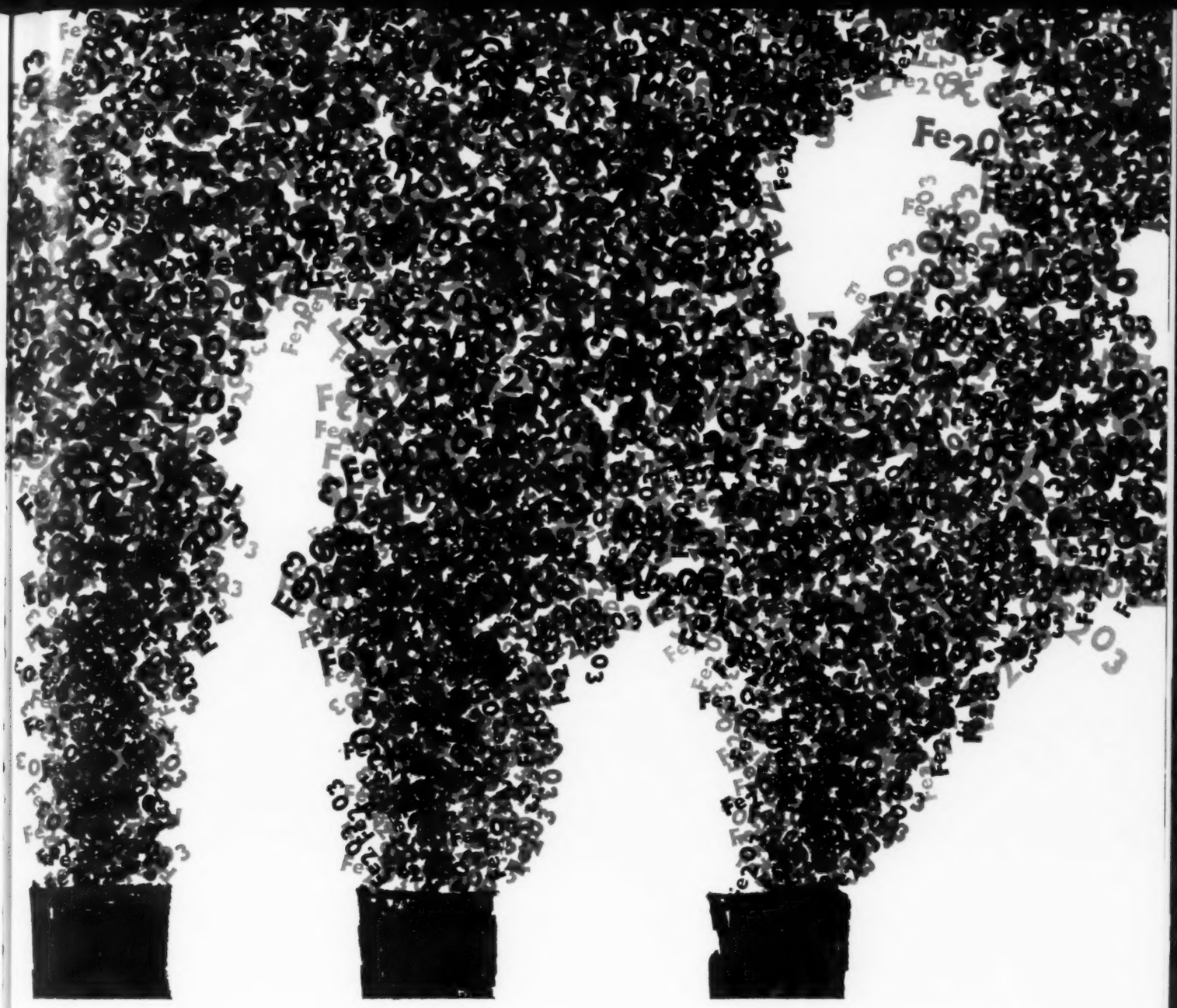


USING O_2 IN YOUR OPEN HEARTH? Chemico Venturi Scrubbers do more than simply solve the air polution problems brought on by the use of oxygen in steel making. Operating and performance figures indicate that for oxygen steel converters, oxygen lanced open hearth furnaces, electric furnaces and flame scarfing, the Chemico Venturi Scrubber solves those problems with higher efficiency and at lower cost than any other method now in operation. Specifically, these are the advantages of a Chemico Venturi Scrubbing System:

CAPITAL INVESTMENT—Chemico Venturi Scrubbers can be installed for approximately 30-50% less capital cost than required for electrostatic precipitators.

OPERATING AND MAINTENANCE COSTS—Chemico Venturi Scrubbers require so little maintenance and manpower, that over-all operating costs are dramatically lower than for other methods, even though power requirements may sometimes be slightly higher.

CONSISTENT PERFORMANCE—The Chemico Venturi Scrubber attains maximum cleaning efficiency at start-up. This peak efficiency is not decreased by subsequent changes in the gas flow or other variations in process conditions.

COLLECTION AND DISPOSAL—The Chemico Venturi Scrubber collects iron oxide dust wet and recovers it dry—free of contaminants and ready for re-use. It eliminates the common and very serious problem of how to handle and dispose of dry dust collected in an electrostatic precipitator.

WATER REQUIREMENTS—The Chemico closed cycle scrubbing process eliminates water disposal problems and cuts make-up water requirements to a minimum. Normally, no more than 50-100 GPM is needed.

PROCESS FLEXIBILITY—Adjustable Venturi throat permits automatic control of furnace draft while maintaining full cleaning efficiency.

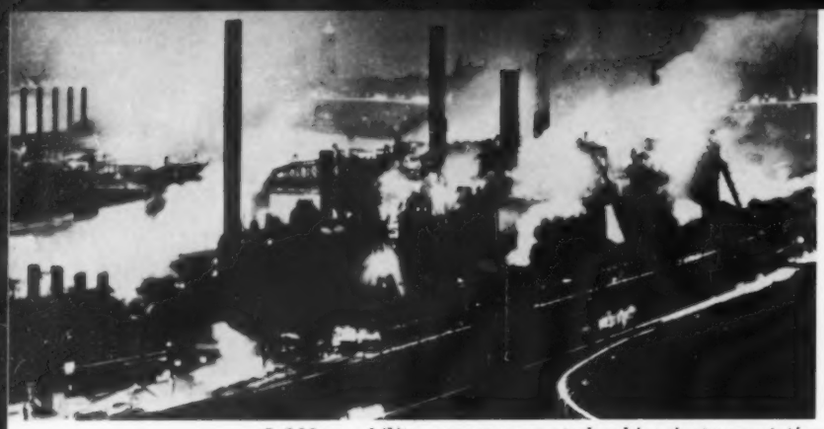
If you are considering the installation of gas cleaning equipment, a Chemico representative would be pleased to discuss performance and cost figures with you. Chemico handles the complete job:

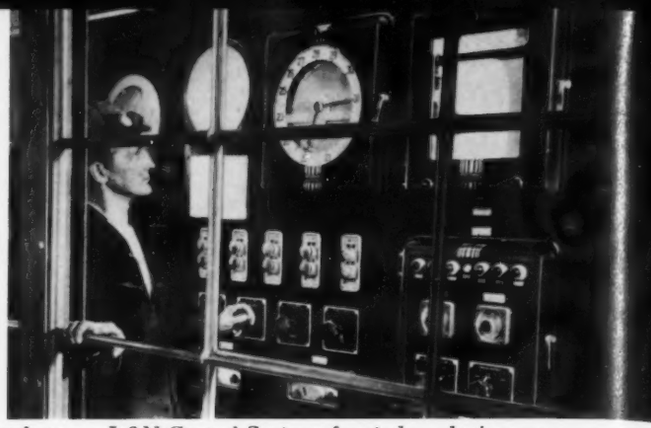
PLANNING—DESIGN—ENGINEERING—CONSTRUCTION and START-UP.

CHEMICO

Chemical Construction Corporation, Gas Scrubber Division, 320 Park Ave., New York 22, New York

Ferndale, Mich. Chicago, Ill. Los Angeles, Calif. Houston, Tex. Bartow, Fla. Birmingham, Ala. Pittsburgh, Pa.





L&N capability encompasses steelmaking instrumentation such as . . . L&N Control Systems for steel producing processes . . .

This is computer control capability

L&N sensing devices . . . L&N gas analyzers . . . Speedomax® indicators, recorders, controllers . . .

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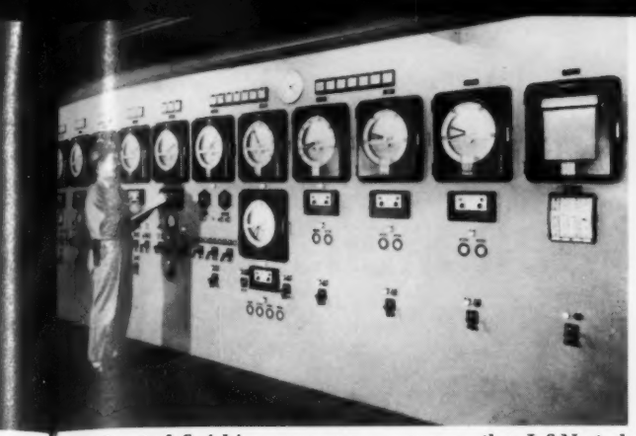
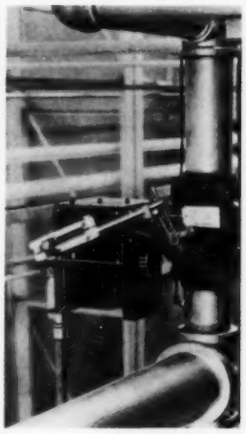
LN3000 Industrial Digital Computer Systems. It includes proven engineering capability . . . L&N feasibility studies . . .



for steel finishing processes . . . many other L&N steelmaking control systems. It includes the development of "hardware" such as . . .

for steelmaking processes...



L&N miniature control systems . . . L&N final control devices . . . L&N industrial data systems . . . L&N closed-loop analog computer systems . .

WHAT YOU SEE in these pictures is only a *small part* of the total capability that L&N—and only L&N—can give you in computer control. L&N is equipped to supply your complete automation system—from primary sensing devices to final actuating drives . . . from precise recorder-controllers to the entire computer system. And you get engineering capability that only L&N can offer because only L&N has the *proven* experience required to design, build and install a successful computer control system for steelmaking processes.

To learn more about L&N's specialized capabilities for automating your blast furnaces, open hearths, oxygen converters, soaking pits, annealing and finishing lines, and other steel plant processes, take the first step now: Call your nearest L&N office or write 4942 Stenton Ave., Philadelphia 44, Pa.

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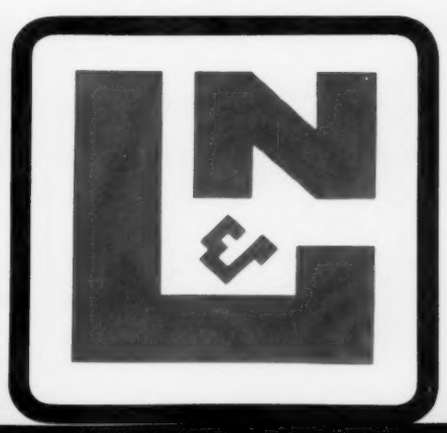
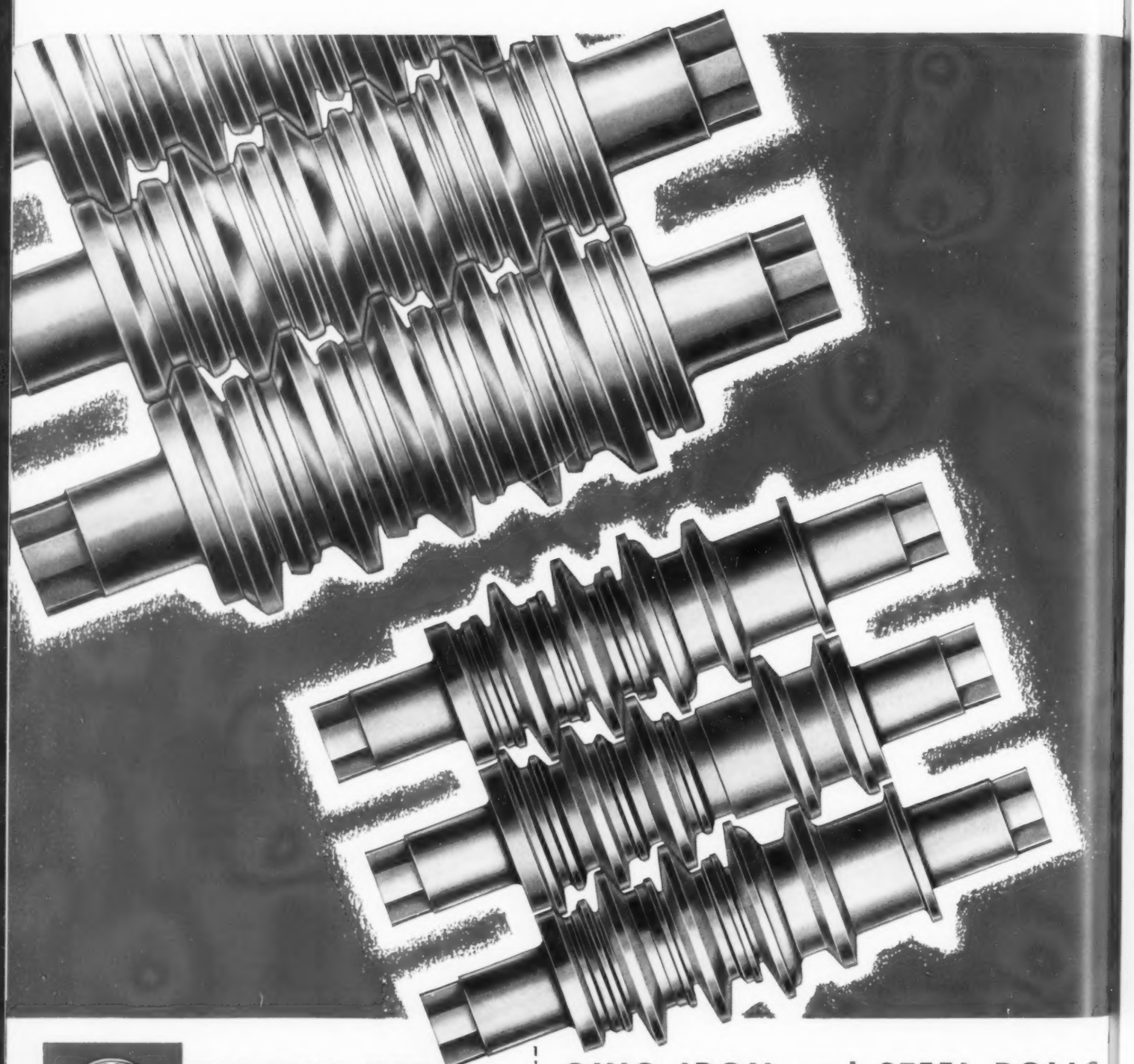


Ohio Rolls

Shaping Metal for all Industry



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OR-51

Industry News...

U. S. STEEL OFFERS NEW THIN TIN PLATE GRADE

△ Development of "Ferrolite 10," a new grade of "lighter, thinner" tin plate priced fifteen cents per base box lower in all basis weights than present Ferrolite, was announced by United States Steel Corp.

Now commercially available, the new grade has a coating of one tenth pound of tin per base box. Heretofore, Ferrolite was produced in one grade only, with a quarter pound of tin coating per base box.

"Addition of 'Ferrolite 10' enables us to offer canmakers a wider range of material," said Richard F. Sentner, executive vice president—commercial, for United States Steel.

"At the outset, can manufacturers believe 'Ferrolite 10' will find a ready use in cans produced for frozen citrus juice concentrates and motor oil," he said. "This product also has many other potential uses, and it is expected that further experimentation will develop these additional applications."

Further development work on this and other products for the can manufacturing industry is continuing. Even lighter basis weights than those now available appear likely in the foreseeable future, according to the U. S. Steel announcement.

REPUBLIC PLANNING NEW BRIGHT ANNEALING UNIT

△ Republic Steel Corp. has announced plans for what will be the largest bright annealing facility in the industry. The nation's third largest steel producer expects to have the new unit ready for start-up in late January, 1962, in Massillon, Ohio. It will be capable of turning out sheets up to 60 in. wide and up to $\frac{3}{16}$ in. thick. Annual capacity is estimated at 55,000 tons.

The company already has the necessary mill and processing equipment to produce standard finishes of stainless steel in widths up to 72 in. inclusive.

The rapidly growing importance of bright annealed stainless steel for flat-rolled applications in the automotive and other fields prompted the company's entry into the field, it was said. Republic only recently announced the start-up of a smaller vertical bright annealing line, also in Massillon, which provides stainless steel strip up to 24 in. in width and in thicknesses 0.008 to 0.070 in. Annual capacity is given as 24,000 tons. The 24-in. furnace can handle all of Republic's Enduro grades.

In addition to increased demands for bright annealed products in the automotive industry, Republic noted, the appliance, utensil and cutlery, food preparation, serving and sanitary equipment fields represent a rapidly expanding market.

In the automotive industry, the swing is definitely to bright annealed stainless for trim, wheel disks and other items, they said. The process gives a brighter finish than the conventional annealed and pickled product. Also, particularly in the case of Type 430, bright annealing can offer better corrosion resistance. In many cases, bright annealed stainless needs little or no buffing and polishing after forming.

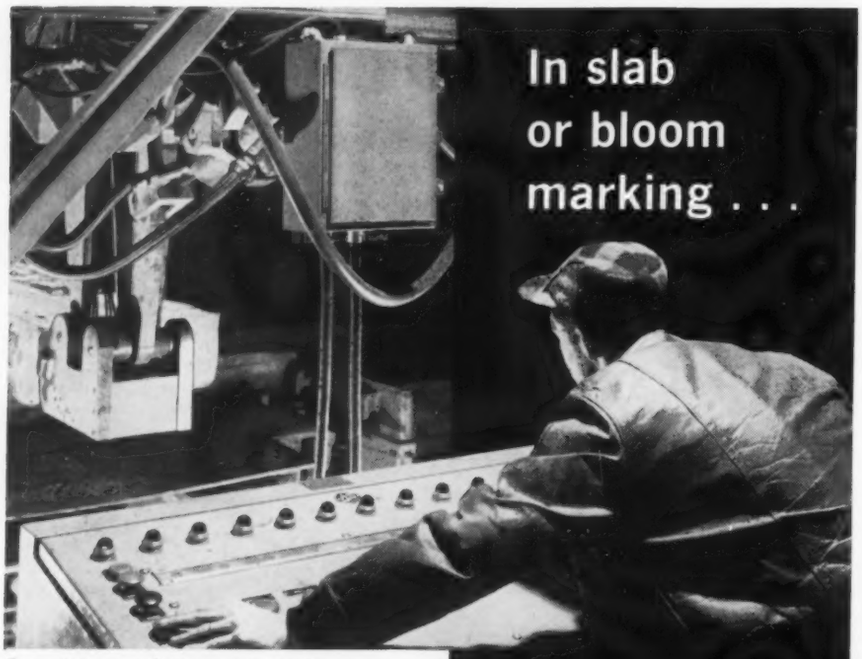
In the consumer area, it was suggested that kitchenware, cookware, flatware, hospitalware and decorative trim for appliances were a few of the many products where bright annealed stainless is finding ever-increasing use.

CHANGING WORK ROLL ON ARMCO COLD MILL

This close-up shows the rolls of a new 50-in. cold mill at Butler works of Armco Steel Corp. It is one unit in the $80,000,000 program to expand the Butler works production of specialty steels. The works was described in some detail in the August issue of Iron and Steel Engineer.

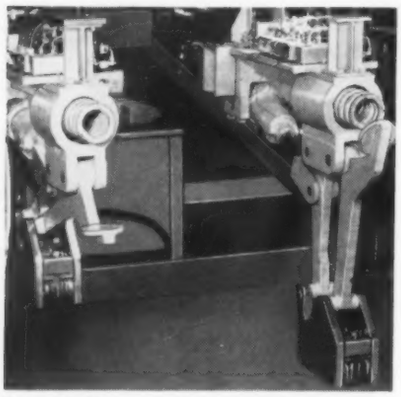
LUKENS TO ADD ANOTHER ELECTRIC FURNACE UNIT

△ Lukens Steel Co. announced it will build a second 100-ton electric

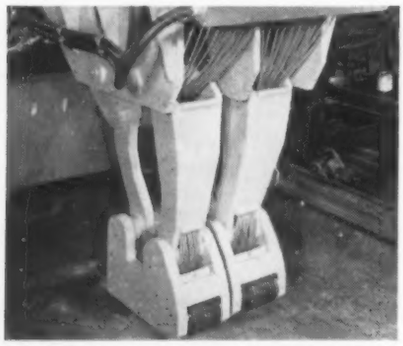


In slab or bloom marking . . .

Operator presses button to actuate stamping cycle or change characters—installed at a transfer table.



Twin units for automatic consecutive numbering of 2½" bar billets—for installation along edge of cooling bed.



Double-headed Slab Marker with 18 stamping wheels, photographed during testing—for installation over a roller line.

CUNNINGHAM HAS THE EXPERIENCE

17 UNITS IN SERVICE . . . MORE ON ORDER

Under constant development for more than 13 years, Mecco Safety Slab Markers are the industry's most advanced—*the most thoroughly service-proved,* by a margin of hundreds of thousands of tons.

We'll gladly consult with you on any phase of steel industry marking. *May we send technical bulletins on Slab Markers?*

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PITTSBURGH 33, PENNA.

furnace which it expects to place in operation within 12 months.

Charles L. Huston, Jr., president of Lukens, said the directors have given final approval to the $6,250,000 project, which will include a scrap handling area, a mold stripper building and a mold storage and preparation building.

The furnace will be erected adjacent to the company's other electric furnace, which was part of a $33,000,000 expansion program completed early in 1959.

United Engineers & Constructors, Inc., will do the construction. Lukens engineers and those of United Engineers & Constructors will do the engineering work jointly. The engineering phase is already under way with actual construction to start within a month.

Mr. Huston noted that the excellent performance of Lukens' first electric furnace showed the wisdom of this kind of steelmaking equipment for the carbon and alloy steel plate products the company makes.

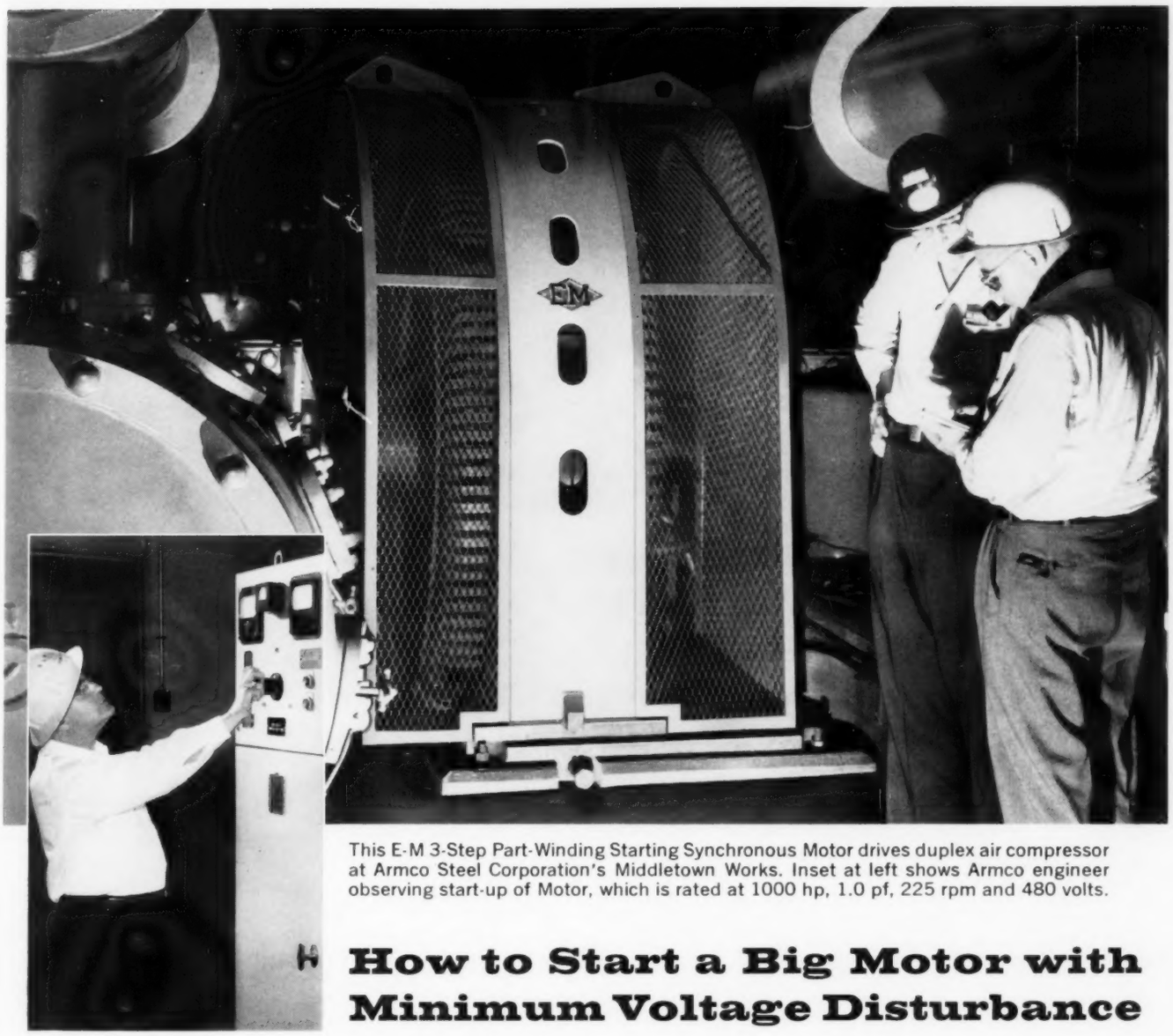
"The project," he said, "is another step by Lukens to keep competitive its cost of steel production and to provide a modern facility with the flexibility to meet customer requirement."

COAL INJECTION RIGHTS ACQUIRED BY KOPPERS

△ Koppers Co., Inc., has entered into an agreement with Bituminous Coal Research, Inc., which gives Koppers exclusive rights to a device and related techniques to be applied to metallurgical furnaces for the controlled introduction of solids into a stream of air against substantial pressures.

Koppers plans first to apply this method, which includes a device called a "coal pump," to the injection of coal into blast furnaces. The coal pump was developed by the Locomotive Development Program of Bituminous Coal Research, Inc., in their work on coal-fired gas turbines.

Bituminous Coal Research, Inc., will make available to Koppers the findings resulting from about twelve years of research on this application. In addition, the two organizations are conducting additional development programs on specific applications to enable Koppers to present to industry a highly-perfected in-



This E-M 3-Step Part-Winding Starting Synchronous Motor drives duplex air compressor at Armco Steel Corporation's Middletown Works. Inset at left shows Armco engineer observing start-up of Motor, which is rated at 1000 hp, 1.0 pf, 225 rpm and 480 volts.

How to Start a Big Motor with Minimum Voltage Disturbance

PROBLEM: An air compressor at Armco Steel Corporation's Middletown Works needed a big motor drive. This motor was to draw power from a heavily-loaded transformer. Because of other machinery on the same line, voltage disturbance during starting had to be held to a minimum.

SOLUTION: An E-M Synchronous Motor with custom-designed Part-Winding Starting.

Here's why Part-Winding Starting performs smoothly under tough starting conditions:

Fully Automatic. When the start button is pressed, a group of paralleled stator windings are energized one by one in a pre-determined sequence. Acceleration is smooth, positive.

No Transfer Current Peaks. Unlike open-circuit transfer auto-transformer starting, there is no circuit break with high current surge at transfer point. Line disturbance is at a minimum throughout starting.

No Auxiliary Voltage-Reducing Equipment. This means simpler control during starting. And the entire installation takes less space and is far easier to maintain.

Part-Winding Starting, invented and pioneered by E-M, can solve many of your big-motor starting problems. E-M Specialist Engineers will design a motor with two or more step windings to match most requirements. Ask your E-M Sales Engineer for more information.

And for your copy of a Part-Winding Starting technical article in E-M Synchronizer No. 33, write directly to Electric Machinery Mfg. Company, Minneapolis 13, Minnesota.

Specialists in making motors do exactly what you want them to

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Induction Motors • Synchronous Motors • Motor-Generator Sets
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FIRST IN THE STEEL INDUSTRY—ELECTRONIC BILLET-HEATING FURNACE CONTROLS

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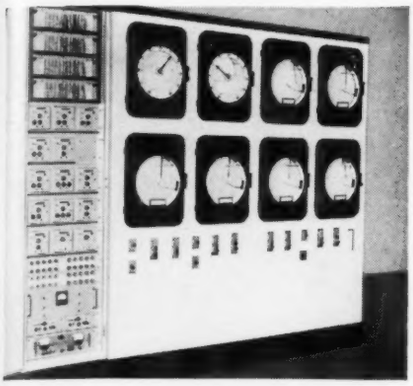


FIRST IN THE STEEL INDUSTRY AT BETHLEHEM'S STEELTON WORKS

A two-zone Rust billet-heating furnace at Bethlehem's Steelton Plant is equipped with Hagan PowrMag® (magnetic amplifier) electronic controls. Hagan systems on this new furnace include zone temperature, fuel/air ratio, furnace pressure, air pressure, and recuperator temperature balance control.

Using Hagan PowrLog® recorders and PowrMag controllers, the system provides for parallel operation of combustion air dampers and fuel oil control valves in each zone. An unusual feature of the furnace is the two stack-type recuperators. These must have waste gas flow regulated so that temperatures are equal in each recuperator, and this must be accomplished by the same dampers that regulate furnace pressure. The control system accomplishes this by using furnace pressure as the primary control impulse, moving both stack dampers in parallel. Temperatures in both stacks are continuously sensed, and a controller moves one of the dampers to maintain the two temperatures at the same level.

This installation is a part of the move towards more centralized control that has interested the steel industry for some time. A Hagan engineer will be glad to discuss how this principle can be applied to your plant. Or, ask for Bulletin MSP-163. Write or phone:

HAGAN

CHEMICALS & CONTROLS, INC.
HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO.
HALL LABORATORIES • BRUNER CORP.

stallation for immediate full-scale application.

The injection of coal into blast furnaces to replace a substantial part of the normal coke fuel will be of economic benefit to this metallurgical process in many areas. In some cases, this injected coal will replace natural gas or fuel oil, both of which have been used commercially. Additional favorable results expected from this process are: benefits to operation accruing from hydrogen released by the coal in the combustion zone, and the more complete utilization of blast furnace gas by the use of higher stove heats.

ROLLING MILL CONTRACT AWARDED TO SCHLOEMANN

△ A modern combined medium section and beam mill, having a monthly production capacity of 30,000 tons, is to be installed by Lorraine Escaut, S.A., at their Longwy steel works. The plant is to be laid out for the rolling of rounds, squares, angles, channels, tees and parallel-flanged beams.

It is scheduled for commissioning in mid-1963. Schloemann Aktiengesellschaft, Düsseldorf, has been awarded the contract for engineering the complete mill and they will be supplying a large part of the rolling mill equipment.

RUSSIANS TO BUILD NEW STEEL MILL IN SIBERIA

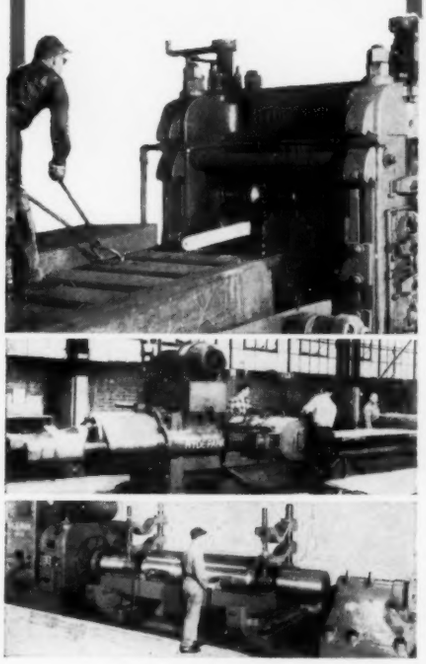
△ A new iron and steel plant to be built in West Siberia will specialize in the production of light structurals, beams, channels and rolled wire. The Gipromez Institute in Moscow is designing the plant's rolling equipment. The 51-in. completely automatic blooming mill is designed to reduce 16-ton ingots into 14½ sq in. blooms. All operations on this mill are mechanized. Each mill roll will be driven by an 8600-hp motor.

The Stalproekt Institute is designing new recuperative soaking pits of high capacity. Ingots will be conveyed to the blooming mill along a circular track by several ingot carriers.

Following the blooming mill will be a continuous billet mill of 12 individually-driven stands alternately horizontal and vertical.

There will also be five high-speed

Hyde Park ROLLING MILL EQUIPMENT



Hyde Park Engineers are always ready to co-operate with you in selecting and applying the rolling mill equipment best suited to your operation.

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Sheet and Strip Mills
Stretcher Levellers
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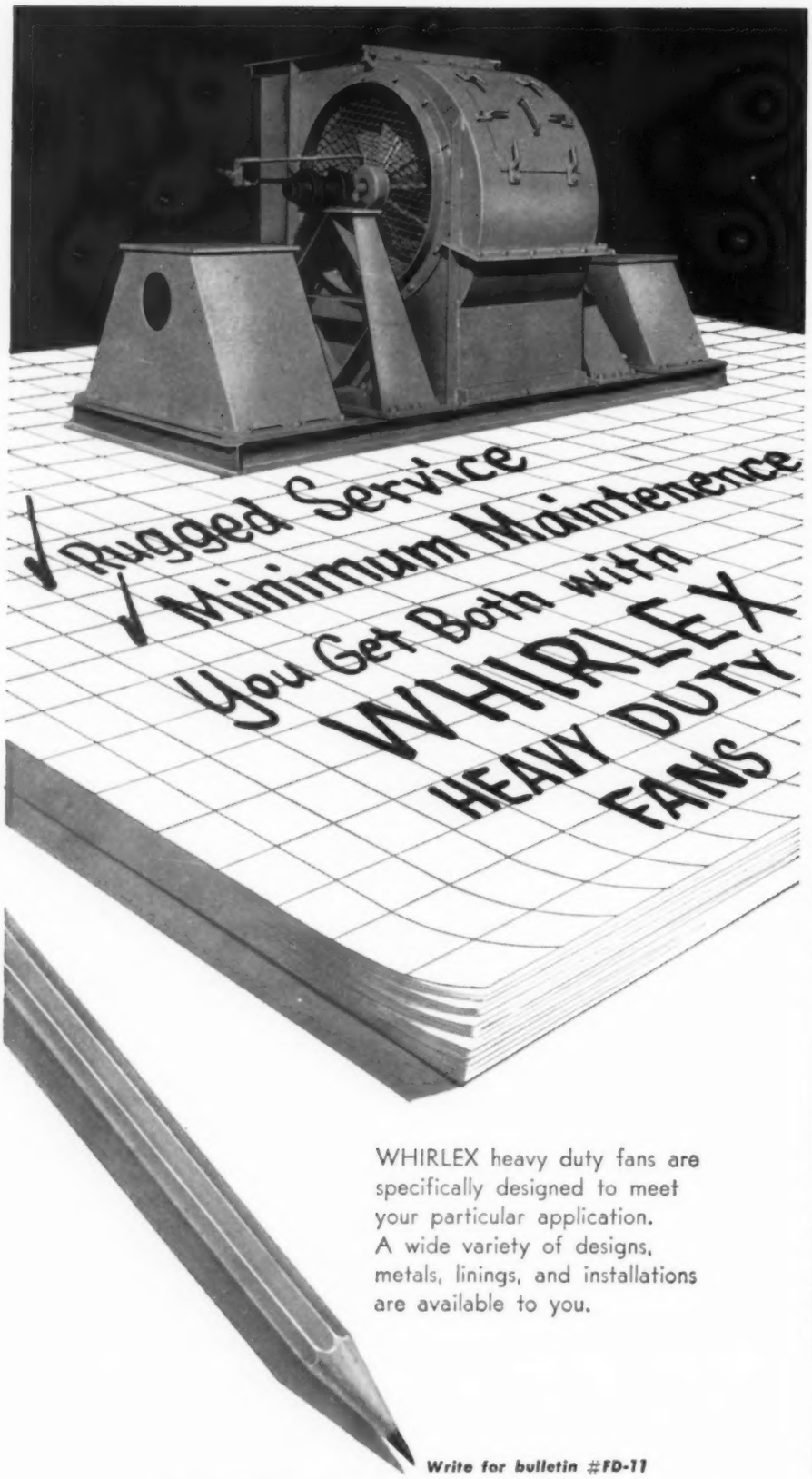

WHIRLEX heavy duty fans are specifically designed to meet your particular application. A wide variety of designs, metals, linings, and installations are available to you.

Write for bulletin #FD-11

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Bag Collectors ■ Mechanical Collectors ■ Wet Collectors
Induced Draft Fans ■ Forced Draft Fans ■ Exhaust Fans
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structural, rod and wire mills. The largest of these is designed for rolling light structurals. Designed by the Research Institute for Metallurgical Machinery, this mill will have 16 work stands with vertical and horizontal rolls. It will work at speeds to 2950 fpm. It will also be used for the rolling of strip for welded pipe.

The plant will also have two continuous 2-strand rolling mills which will produce light sections at speeds up to 3935 fpm. Two other mills will be used for rod. They will be 4-strand units with speeds up to 7870 fpm. It is planned to use butt welding of billets before they are fed into the mills.

Integrated mechanization and automation is to be introduced in all the processes. Among other things, several special mechanized installations will be operating in storages for the inspection and chipping of billets.

JESSOP AND INDIAN FIRM PLAN JOINT VENTURE

△ Jessop Steel Co. is developing a tentative program for a joint venture with Vummidiars Private, Ltd., of India, for the construction of an alloy steel plant in the State of Madras.

Frank B. Rackley, president of Jessop, made the announcement following a meeting with V. Pandurangiah, managing director of the South Indian firm, and A. M. M. Murugappa, internationally-known Indian industrialist and past president of the Federation of Chambers of Commerce and Industries.

Vummidiars is a manufacturer and distributor of stainless steel equipment.

Mr. Rackley said the proposed plant will have an annual capacity of 7000 to 10,000 tons of finished alloys.

"Because of an increasing demand for specialty steels in India," Mr. Rackley said, "that country's planning commission has asked that a high priority be assigned to a program of rapid expansion of a specialty steel industry.

"The proposed new Vummidiars plant would incorporate steelmaking processes developed by Jessop to help meet this demand for specialty steels," he added.

Initially, the proposed plant

Replace old-fashioned couplings with Rockwell-Standard's

BLOOD BROTHERS

HEAVY-DUTY INDUSTRIAL DRIVE LINES

ROCKWELL-STANDARD ENGINEERS specifically designed Blood Brothers Heavy-Duty Industrial Drive Lines to replace couplings in industrial applications. They improve machine performance and efficiency...last longer... give better service than any coupling. They often reduce costs by eliminating the need for bearings and supports required by conventional coupling installations. Wearing parts are quickly replaced and even drive lines can be replaced in 15 minutes!

Available in capacities up to 500,000 torque inch pounds, they are adaptable to a variety of applications—rolling mills, oil field equipment, irrigation pumps, cargo carriers, marine drives, logging winches, mining machinery and many others.

Blood Brothers Industrial Drive Lines offer these special features:

• Wing bushings that eliminate costly flange yokes and reduce down time during servicing. Simply remove 8 bolts for complete disassembly • Sliding spline provides for quick, easy assembly—variations in mounting locations—longitudinal shaft movements during operation—deflections and temperature changes • Easy access to lubrication fittings.

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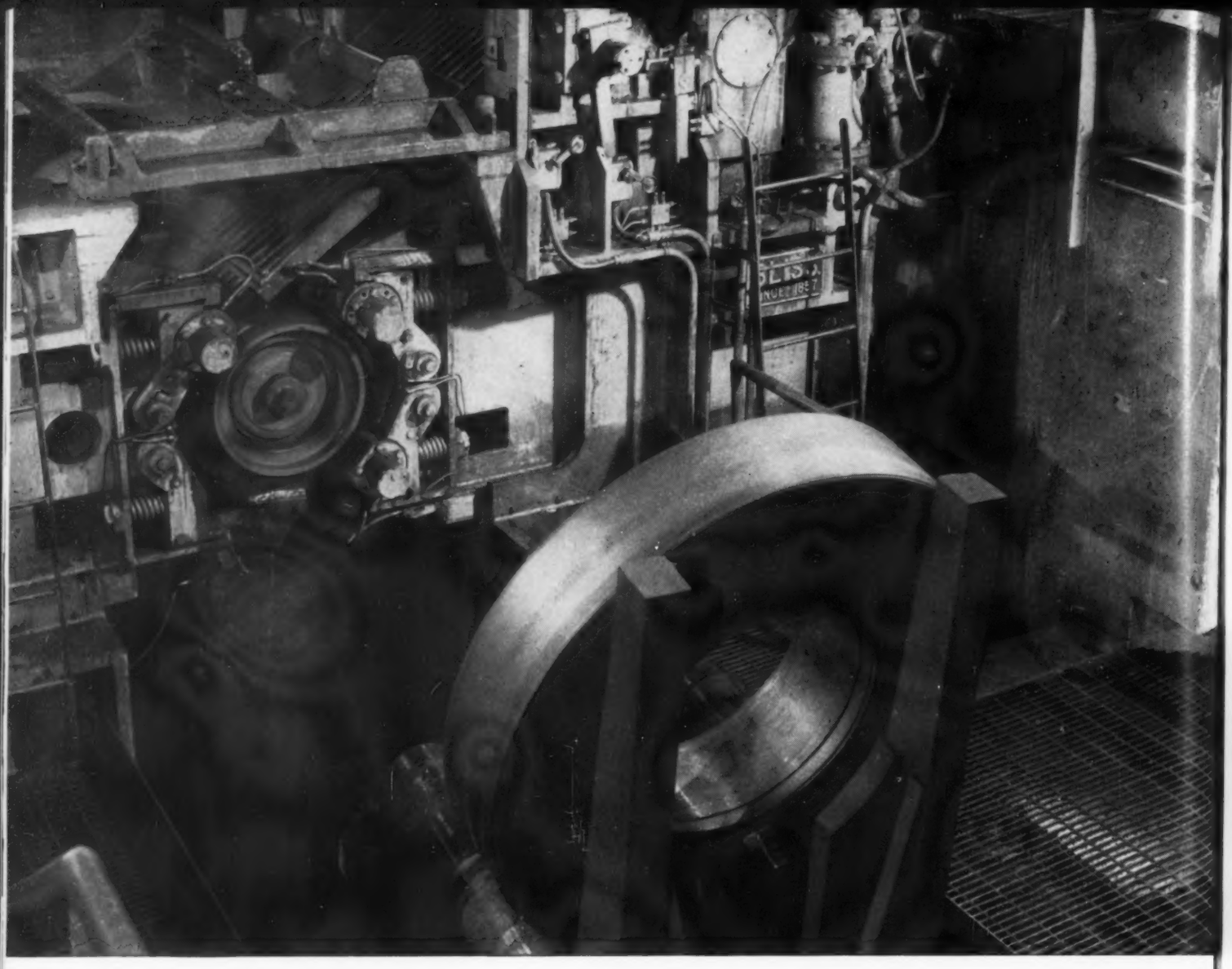


New downcoiler plays key role at Acme Steel's new hot strip mill

Among important Bliss mill auxiliaries selected by Acme Steel for the new hot strip mill at its Riverdale, Ill., plant, is the new downcoiler shown here. The coiler was designed with two objectives: simplicity and flexibility. Simplicity, by keeping the number of moving parts to a minimum for low maintenance costs and reduced downtime. Flexibility, by designing to permit the use of one, two, three or four blocker rolls without mechanical or electrical alterations.

Other units designed and built by Bliss' Rolling Mill Division include a combination depiler and furnace feeder, a furnace peeler, a crop shear and the side gauges at the end of the runout table just before the downcoiler.

Many of the most modern installations in the metal rolling industry carry the Bliss trade mark. For a portfolio of these mills and auxiliary rolling equipment, write us for a complimentary copy of our 84-page Rolling Mill Brochure, Bulletin 40-B.

Bliss is more than a name . . . it's a guarantee

E. W. BLISS COMPANY, Rolling Mill Division, Salem, Ohio

Rolling Mills • Mill Auxiliaries • Amerigear/Bliss Flexible Spindles

BLISS
SINCE 1857

Subsidiaries: E. W. Bliss (Canada) Ltd.; E. W. Bliss (England) Ltd.; E. W. Bliss Co. (Paris) France; E. W. Bliss-Henschel G. m. b. H., Düsseldorf, West Germany; The Matteson Equipment Company, Inc., Poland, Ohio

would produce alloys in the form of ingots, forgings, flats and bars.

The government already has issued a license to Vummidiars for construction of the plant and the state government of Madras has indicated a willingness to participate in financing the venture with equity capital.

Cost of the proposed plant has been estimated at approximately $5,000,000. Jessop, in addition to equity participation in the venture, would supply engineering and technical know-how in its operations.

"By 1965 the government of India plans to produce eight million tons of carbon steels at their four new steel plants," Mr. Pandurangiah said. "Against the background of India's vast industrial expansion program during the next five years, it is estimated that India will need 300,000 tons of tool and alloy steels annually."

The government of India in its new Durgapur alloy steel plant will produce only a small part of these requirements. To meet the shortage, the Indian government has licensed a few private firms to build plants to produce additional capacity.

YS&T PURCHASES LAND AND BLAST FURNACE

△ The Youngstown Sheet and Tube Co. announced that it has purchased 32 acres of land and the "Anna" blast furnace in Struthers, Ohio, from the Pittsburgh Coke and Chemical Co. Cost of the transaction was not disclosed.

The property abuts Youngstown Sheet and Tube's Campbell works and lies between the eastern boundary of company land near the coke plant and Bridge Street in Struthers. Included are the blast furnace and auxiliary facilities.

In announcing the purchase, President A. S. Glossbrenner said the property provides additional space for growth of the Campbell works, but added that no immediate use is planned.

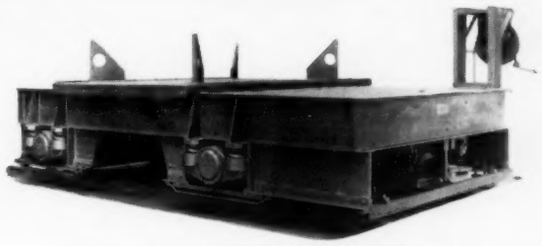
PECOR TO FURNISH GIANT SCRAP CHARGING CAR

△ The world's largest scrap charging machine for steel mill service is now being built by Pennsylvania Engineering Corp. PECor is furnishing Great Lakes Steel Corp. with a 3000 cu ft capacity car for use in charging scrap to the two 300-ton basic oxygen furnaces being placed in service next year. The basic oxygen furnaces also will be the world's largest.

"Traditionally, charging the furnace with sufficient volumes of scrap quickly enough through mouth openings which must be held to a minimum size has been one of the main problems in efficient basic oxygen steel operation," said A. L. Davis, Pennsylvania Engineering president. "We believe this giant scrap charging machine will solve the scrap charging problem at Great Lakes Steel."

The self-propelled scrap charging car will have two scrap boxes, each with a capacity of 1500 cu ft or 55 tons of scrap. The steel plate boxes will weigh about 85,000 lb each. Loaded weight of the car will be approximately 700,000 lb.

Based on a "jam-proof method," this design dumps scrap boxes hydraulically and also allows dumping by overhead crane in case of power or mechanical failure.



Scrap Bucket Charging Car with remote dial.

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ACCURATE...
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ELECTRONIC DIAL SCALES

■Atlas Electronic Scales have the accuracy and ruggedness which makes them suitable for the heaviest service. They are credited with being the most simple of any electronic scale on the market.

■A special feature is that many of the parts of the Atlas Electronic Dials are interchangeable with Atlas Mechanical Scales, which have earned an outstanding position in heavy-duty weighing service.

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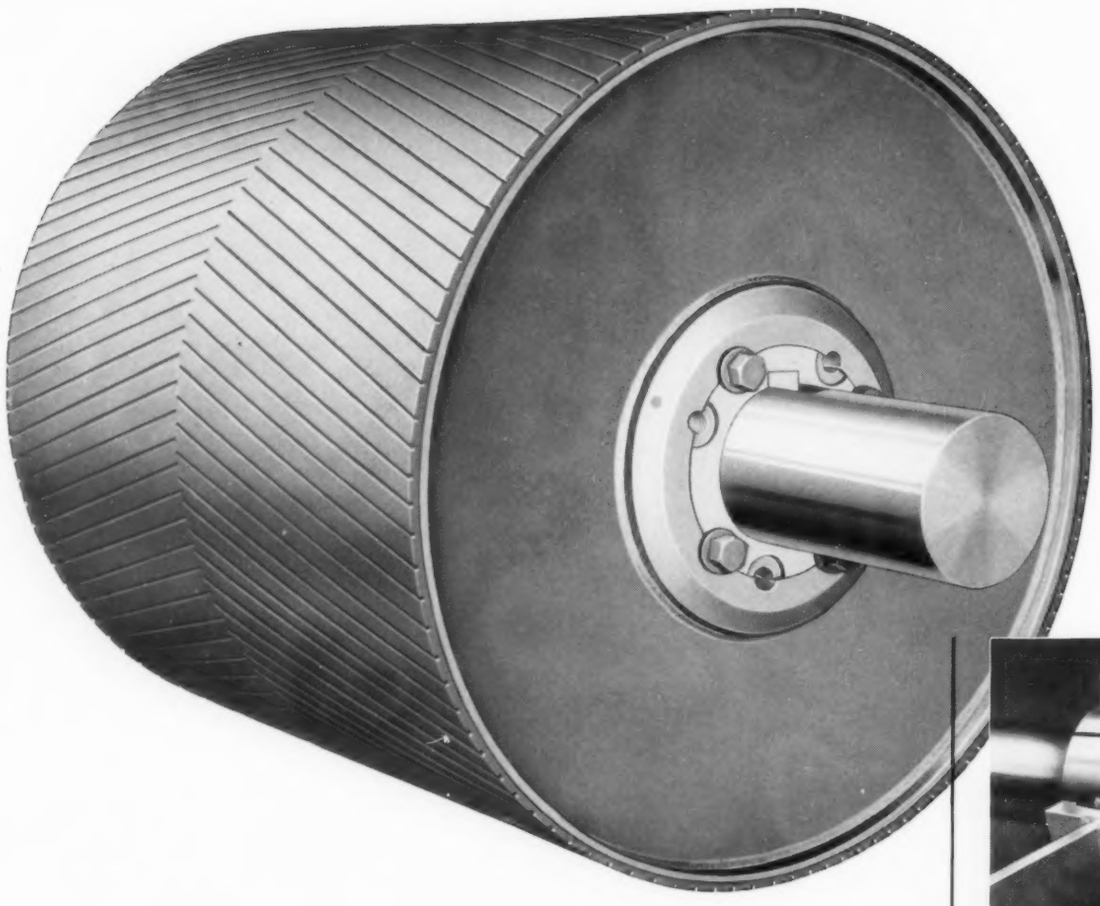

AMERICA'S NO. 1 STEEL CONVEYOR PULLEY!

There are more Taper-Lock Steel Conveyor Pulleys than any other operating on big jobs. Why? Simply because of the dependable performance they deliver under the toughest conditions.

The rims, discs and hubs are *steel* — and they are fused together into jointless drum construction for (1) maximum strength with minimum weight, (2) exclusion of dirt, water and steam, (3) terrific shock resistance. Every weld is made by the submerged arc process giving deep penetration and exceptional strength. Rims are accurately die formed in the smaller diameters and rolled in the larger diameters. Pulleys with 26″ and wider faces have interior discs that add to the trueness, rigidity and strength of the rims.

Dodge offers the world's biggest range of stock sizes. Diameters from 6 inches to 8 feet — all face widths, crowned or flat. Standard or special rubber lagging available. Ask your local Dodge Distributor — or write us for a technical bulletin.

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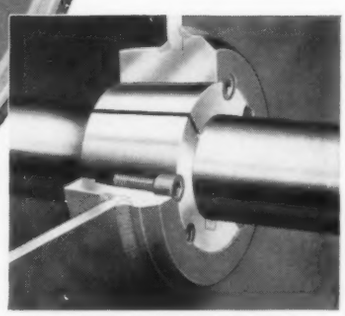
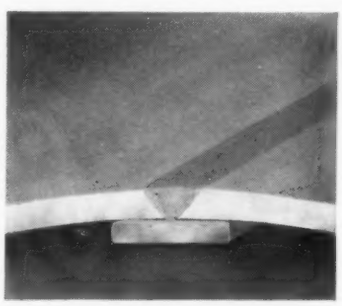
CALL THE TRANSMISSIONEER, your local Dodge Distributor. Look under "Dodge Transmissioneer" in the white pages of your phone book. Factory trained by Dodge, he can give you valuable assistance on new cost-saving methods.



No "walking" on the shaft with Taper-Lock. Full length contact of hub. Holds under heavy loads and shock. Easy on — easy off.

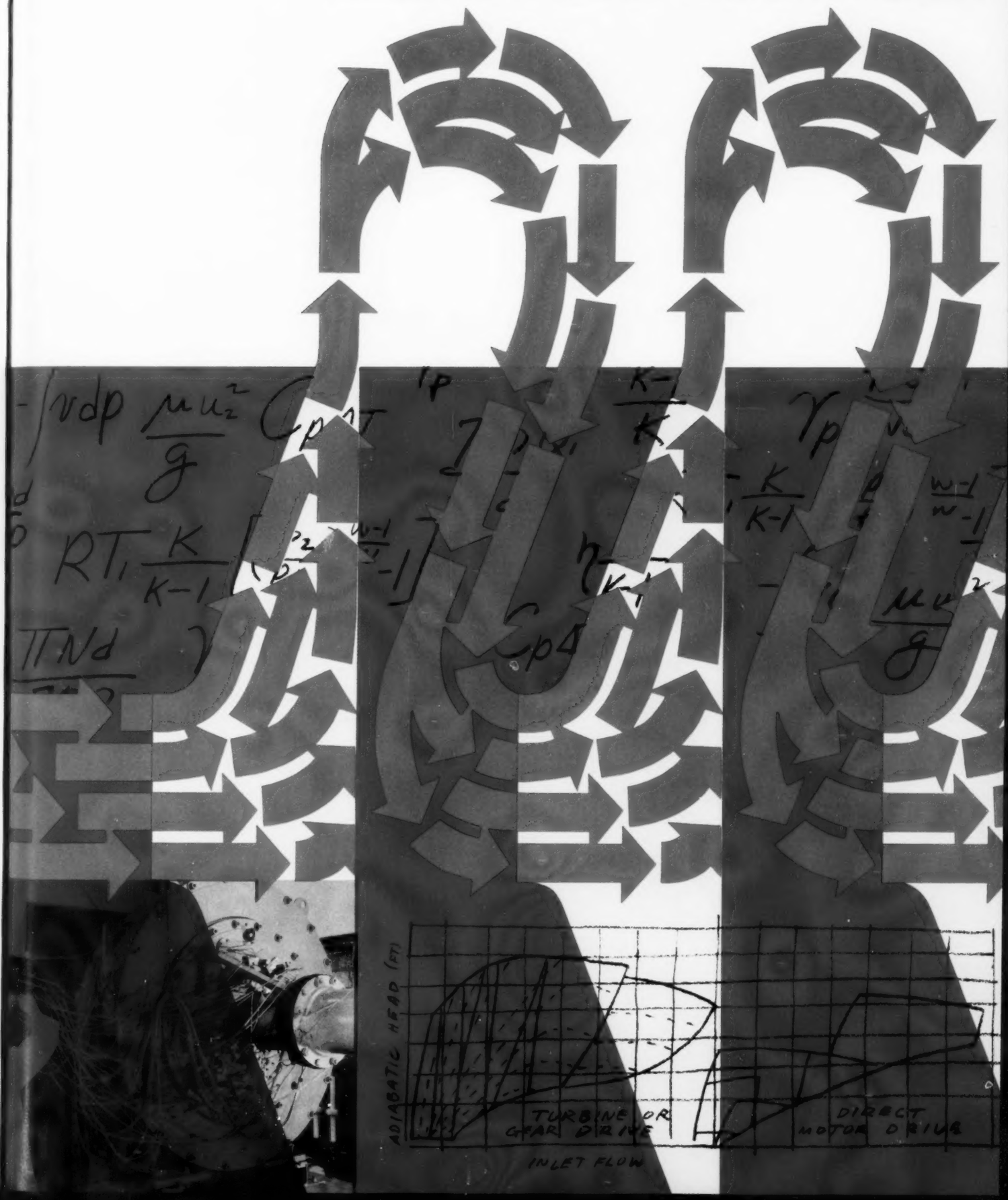


Patented Back-up Bars give full rim strength through 100% weld penetration. Diametrically opposed bars insure balance.

Jointless construction creates a drum fully sealed against conveyed materials of all kinds as well as dirt, water and steam.

SOLID FOUNDATION FOR PROGRESS

Engineering Research is the backbone of Elliott developments in centrifugal compressor design. Persistently exploring new paths to broader application flexibility, better operating efficiency, increased reliability, Elliott compressor research engineers study aerodynamic, thermodynamic, mechanical, metallurgical and related subjects to improve and perfect the performance of Elliott compressors. **ELLIOTT COMPANY**



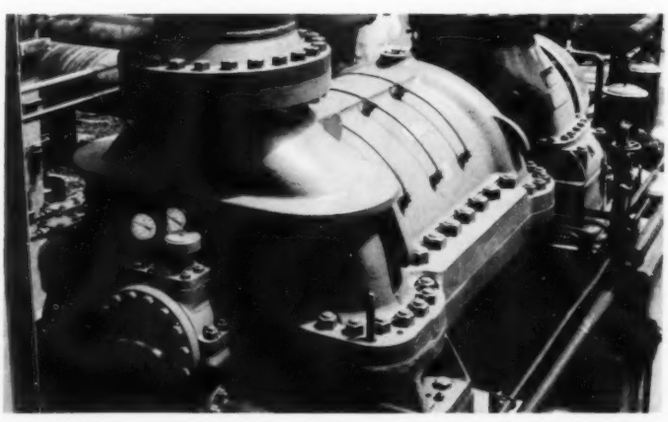
IS BEING DEVELOPED

HERE This is a part of the Elliott compressor development facility—a highly-sophisticated proving ground for new ideas.

With the research equipment pictured here, new compressor wheel designs, new diffuser and return channel patterns, new inlet and discharge geometry can be evaluated. A multiplicity of temperature and pressure probes report conditions at test stations from inlet to discharge. Compressor components under study can be operated as an open air system or as a closed loop.

The knowledge gained with this and other unique research facilities will assure continued advances in the design and application of Elliott compressors.

This is one of the Elliott machines now in service into which has been incorporated fundamental basic knowledge already gained through the use of the above facility.



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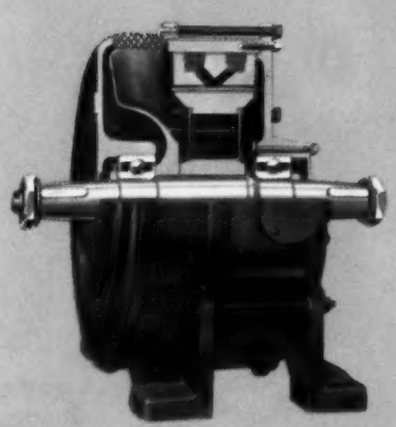
This P&H overhead crane handles these tall foundry flasks and huge, yet fragile, cores as gently as a mother lifts a baby. With P&H Electronic Stepless control, in combination with P&H Magnetorque braking, the operator performs all the work of assembling flasks and cores smoothly, precisely, confidently—every time. Result: maximum production with *zero* damage.

You get this kind of performance only from a perfect marriage of operating and control characteristics . . . something Harnischfeger guarantees. Harnischfeger is the only crane manufacturer that makes . . . and matches . . . all electrical as well as mechanical components. And because we *make* all the parts, rather than *buy* and *assemble* them, your cost is agreeably low!

Next time *you* need any size overhead crane, send your inquiry to the world's largest crane builder: Harnischfeger, Milwaukee 46, Wisconsin.



Cutaway view of P&H electric load brake... heart of P&H Magnetorque Control... which consists of a simple, indestructible rotor and stationary field through which braking forces are exerted electromagnetically.

HARNISCHFEGER **P&H**

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P&H HEVI-LIFT® HOISTS

handle steel plate with a feather touch!

P&H Balanced Design Hevi-Lift hoists handle steel plate and welded structures in this metal-fabricating plant with precision and safety. Eight-push-button, variable-speed control permits the operator to handle even the largest, most awkward sheets quickly, accurately, safely.

The P&H hoists are mounted on single-leg gantries to provide complete 3-dimensional range of movement. In effect, they operate as junior-sized overhead cranes in this particular area of the plant. They are designed to work with the big P&H overhead cranes — seen in the background — that serve the entire plant.

Every part of the Balanced Design hoist has been balanced or matched with every other part for maximum strength, temperature, and performance characteristics. Important in a plant like this? You bet! You'll find Balanced Design Hevi-Lifts stand up far longer under heavier duty cycles, and with less maintenance, than any other hoist made today.

Find out more about these outstanding hoists. Write for bulletin H-55. Dept. 238, Harnischfeger Corporation, Milwaukee 46, Wisconsin.

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P&H
ELECTRIC HOISTS

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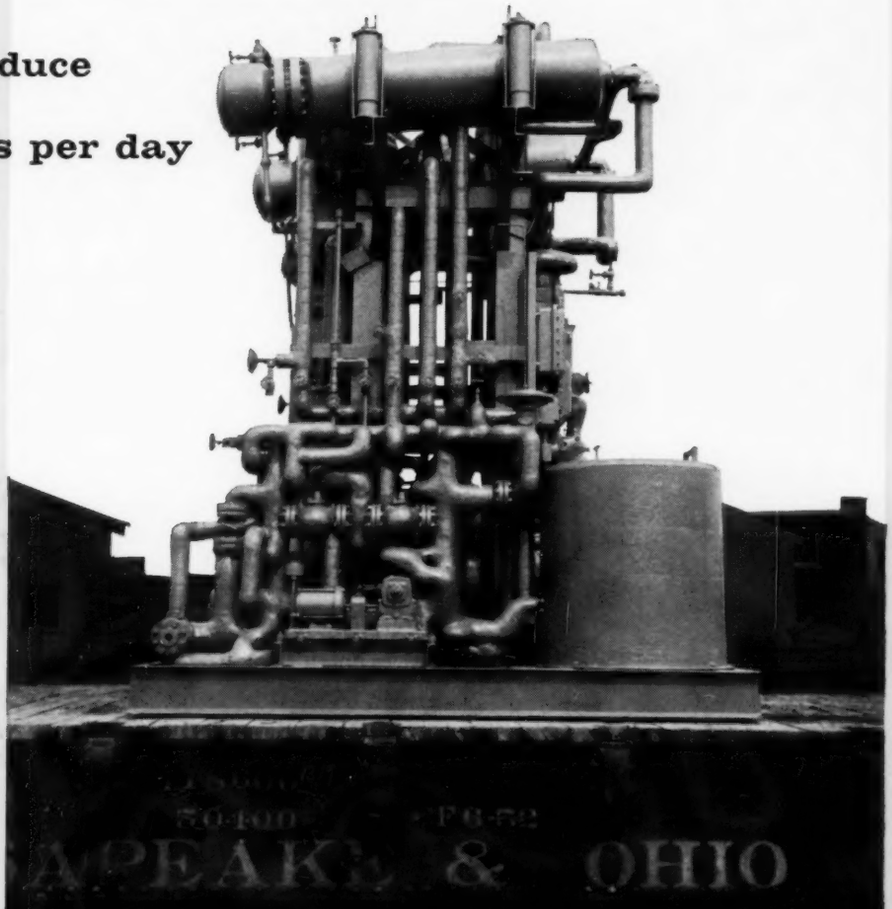
NEW COMPACT GIRDLER HYDROGEN SULFIDE UNITS produce from 1 to 5 tons per day economically!



Solves the need for hydrogen sulfide gas in quantities not practical to handle by cylinders Girdler can now offer you low cost compact hydrogen sulfide package units with capacities from 1 to 5 tons per day. The small unit will produce up to 2000 pounds per day, and a larger unit produces from 2000 to 10,000 pounds per day. They will also operate efficiently and economically at a fraction of their rated capacities.

They utilize a simple new Girdler process based on the reaction of hydrogen with liquid sulfur at elevated temperature and pressure to produce hydrogen sulfide gas. The complete units are fabricated at Girdler's shop and are shipped partially assembled on skids with a minimum of work to be done at the plant site. Operating requirements include hydrogen, liquid sulfur, electric power, steam, and cooling water.

Write for full information on new Girdler Hydrogen Sulfide compact Units today. Take advantage of Girdler's know-how and proven experience in the field of high-temperature, high-pressure processing plants.

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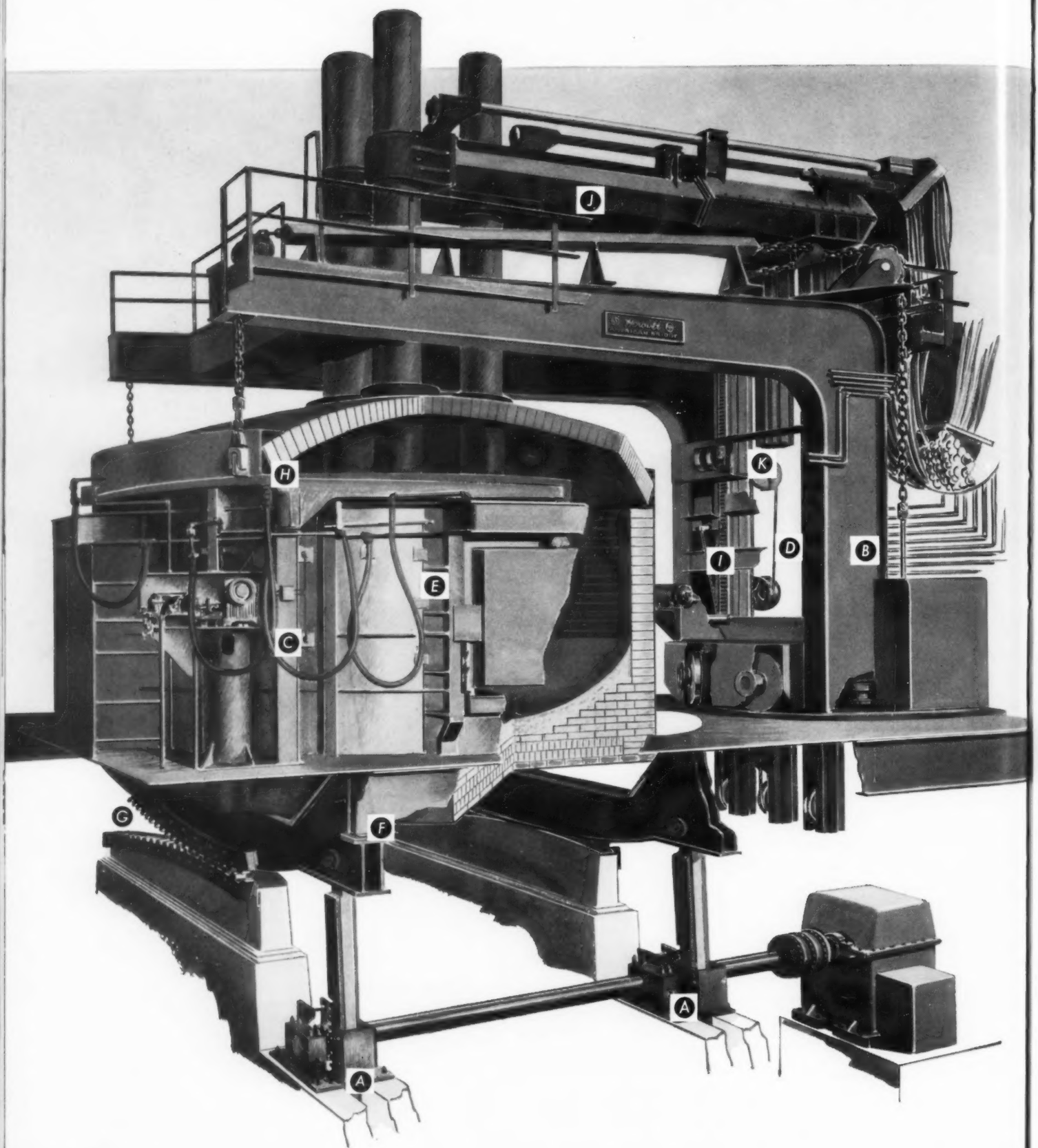
More Steel...Better Steel...Faster



This mark tells you a product is made of modern, dependable Steel.

with a Heroult Electric Furnace

You can increase your steelmaking efficiency and get better steel in the bargain with a Heroult Electric Arc Furnace. Here's why: Heroult Furnaces heat fast — make more melts per day. Heroult Furnaces lower costs through high yields per heat and small scrap losses in charging. And, Heroult Furnaces improve steel quality by reducing sulfur and phosphorous content.

If you're looking for performance, efficiency, economy and low-cost maintenance, consider these features:

1. Heroult Furnaces are 100% mechanically operated. Including **(A)** heavy rack-and-pinion-type tilting mechanism, **(B)** motor-driven, rotating, jib-type roof swing, **(C)** winch-operated, water-cooled, jib-type door-lift mechanism, and **(D)** high-speed, electro-mechanical electrode-positioning mechanism.

2. Cage-type shell construction with shell plates loosely attached **(E)** to heavy supporting structure. This construction minimizes shell warping and allows easy replacement of damaged shell plates.

3. Operating mechanism independently supported. The tilting platform on which all operating mechanisms are supported is attached directly to the rockers independent of the shell structure **(F)**. Thus, operating mechanisms are unaffected by shell distortion.

4. Water-cooled, Skew Back Roof ring. This feature **(H)** eliminates the need for special skew-shaped roof refractories.

5. Electrode Mast Safety Device. This spring-loaded, rack-and-pawl-type device **(I)** provides positive protection against damage resulting from electrode winch cable breakage.

6. Square-section, Water-Cooled Electrode Mast Arms. This design **(J)** guarantees a rigid connection between mast and mast arm, thus helping to maintain proper electrode position.

7. Remote-Controlled Electrode Clamps. This device, of the spring-clamp, air-release type, is located inside of the rear section of the water-cooled mast arm where heat cannot affect it.

8. Square-Sectioned Electrode Mast. This design feature **(K)** developed by American Bridge, assures proper guiding and electrode positioning.

9. Rockers. The heavy fabricated steel curved top and bottom rockers **(G)** minimize forward travel during tilting. These rockers are designed so that the furnace will tend to return to horizontal position from any degree of tilt.

American Bridge constructs Heroult Furnaces for all types of arc melting, in charge capacities from 6,000 lbs. to 400,000 lbs. with shell sizes ranging from seven feet up. They are equipped with roof-removing mechanism for fast top charging. They can be furnished with a non-magnetic shell bottom section to accommodate induction-stirring equipment. Gantry-type top-charge furnaces, door-charge furnaces and special furnaces for duplexing and non-ferrous melting are also available. Your crew can easily maintain a Heroult Furnace. Check American Bridge's complete design, construction and installation service.

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USS

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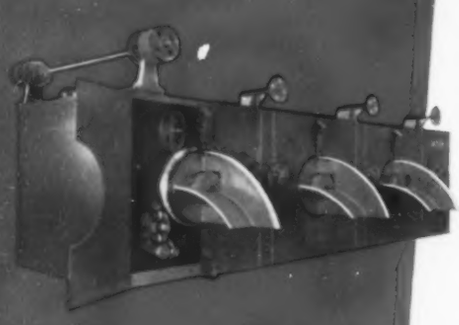
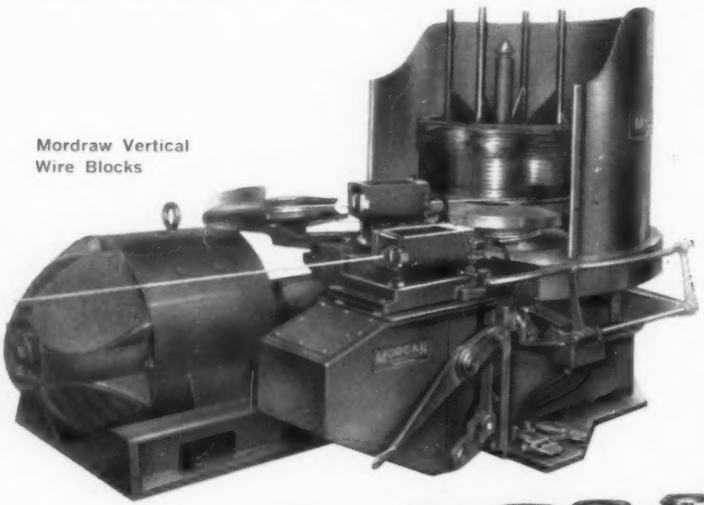
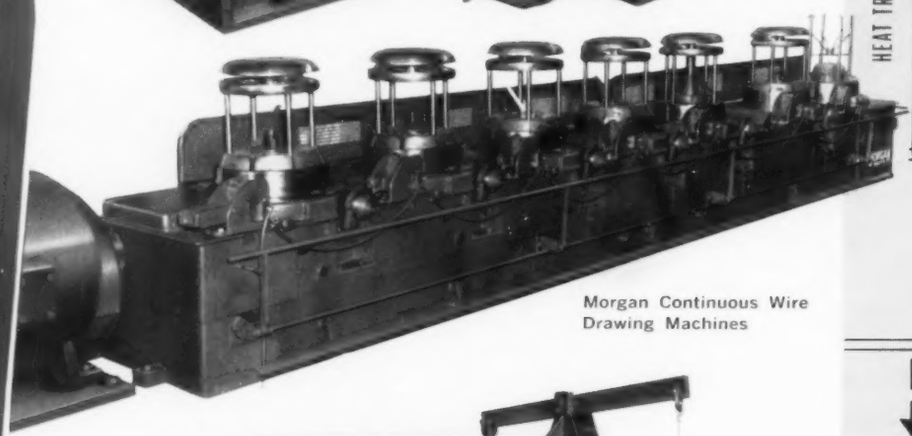
FIRST — Morgan offers you total-concept engineering counsel backed by the industry's broadest wire mill design and operating erection experience. Morgan engineers will study every phase of your individual production

with the only LINE OF WIRE DRAWING MACHINERY complete for any production need

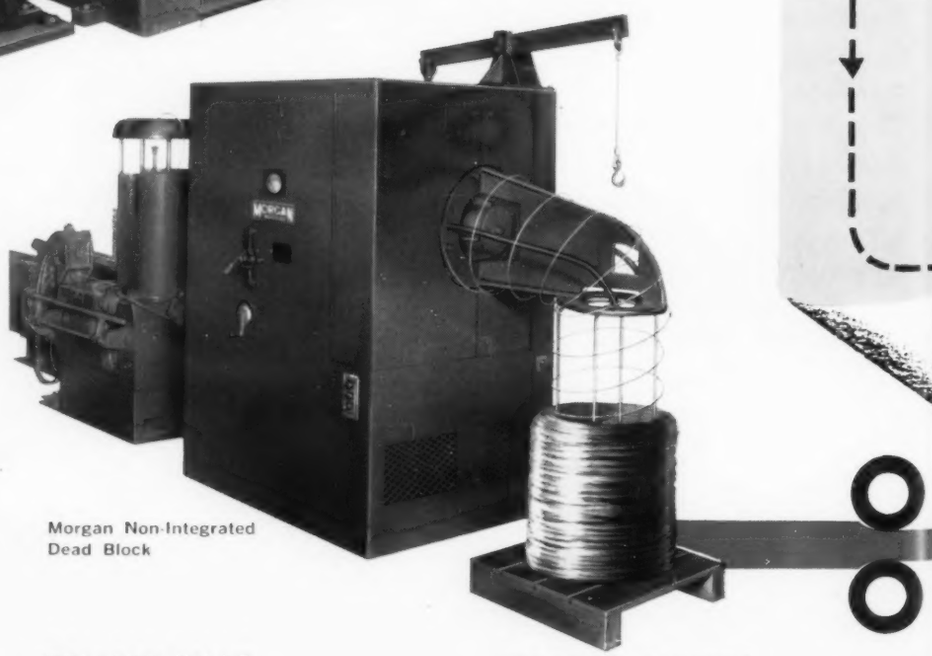




Mordraw Vertical Wire Blocks



Morgan Continuous Wire Drawing Machines



Morgan Non-Integrated Dead Block

HEAT TREATING DEPT.

ROLLING MILLS

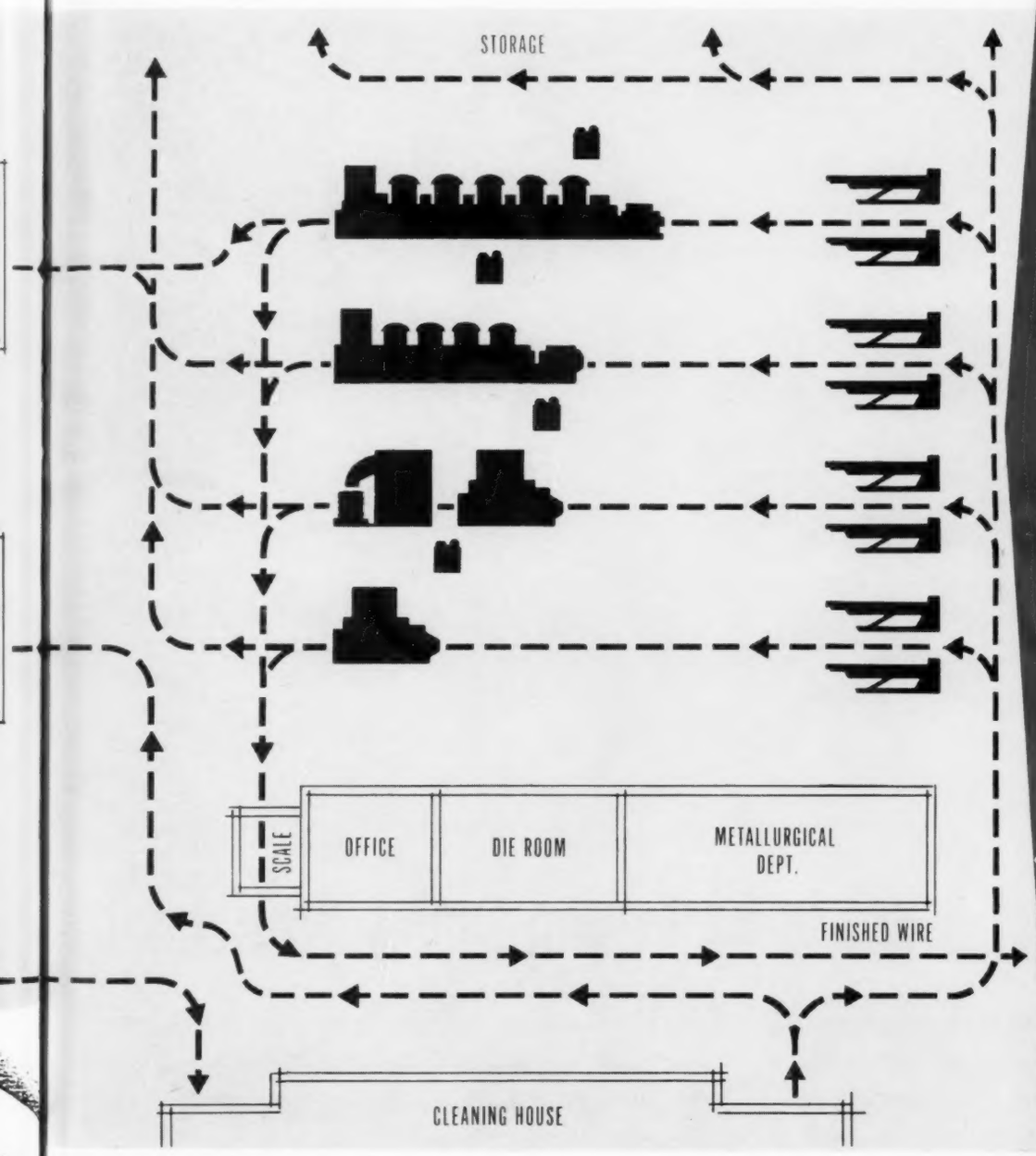
MORGOIL BEARINGS

PUTS PROFITS

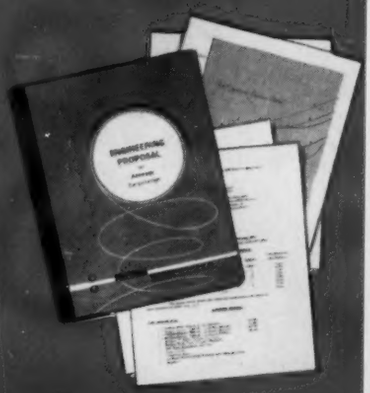
WIRE MILL OPERATION

problem from economic feasibility to long-range potential and will supply basic data for sound decisions.

SECOND — You have available the complete line of Morgan Wire-Drawing machines and accessories . . . proven wire drawing equipment with an outstanding record for reliable, cost-cutting operation. Morgan equipment is engineered from the ground up to provide flexibility and economy through the broadest range of operating conditions.



with the only WIRE MILL DESIGN & ERECTION SERVICE complete from study to start-up



CS-6

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MORGAN CONSTRUCTION CO.

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WIRE DRAWING MACHINES

COMBUSTION CONTROLS

Don't get boxed in by oxygen supply problems...

Keep your steel operations flexible by removing all uncertainties about oxygen supply with an Airco tonnage oxygen plant. A plant we build and operate for you — on or adjacent to your site — gives you assurance of supply that only an experienced oxygen producer like Airco can guarantee.

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PROVEN TECHNOLOGY. Making oxygen — like making steel — is a specialized business. Airco has 45 years'

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experience in low-temperature technology . . . design, engineering and construction proficiency that has dotted the country with oxygen plants — including the first on-site oxygen plant for steel. There's no first-plant guesswork . . . late starts . . . long debugging periods that ruin your production schedules.

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HOW WESTERN GEAR SERVES THE STEEL INDUSTRY

WESTERN GEAR HEAVY DUTY SHEAR TABLE . . . SAVES MONEY . . . CUTS BAR WASTE

In response to a demand for an extremely accurate, heavy duty shear table, the Industrial Products Division of Western Gear Corporation designed and manufactured a table, giving the user the most modern equipment of its type in the country. Major features of the new shear table, now in operation, include • Accurate length cutting to ⅛" for a 60' bar • Individual roller drive gearmotors using spiral bevel gears eliminate gear locking • Disappearing side guards • Push-off bars that disappear on the return stroke. ■ If your business is making hot rolled steel bars or light structural shapes, the design features of this new shear table can help increase your production and reduce costs. Or, call on our sales engineers to solve your bar mill machinery requirements . . . whatever they are. **WESTERN GEAR CORPORATION**, Industrial Products Division, P.O. Box 126, Belmont, California – Telephone LYtel 3-7611.

WG INDUSTRIAL PRODUCTS DIVISION

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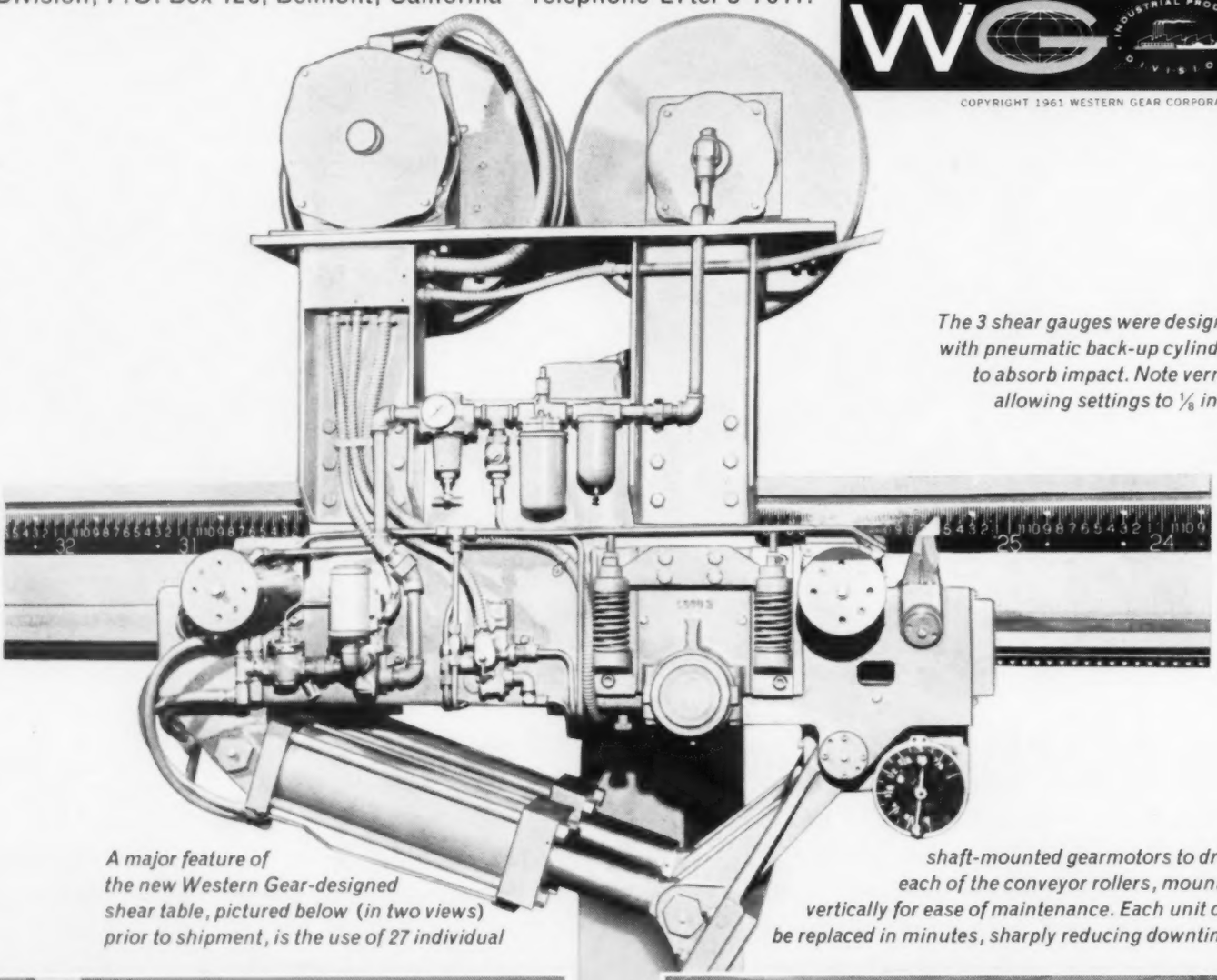
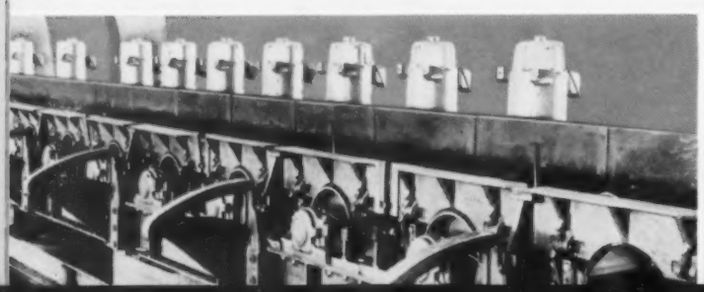
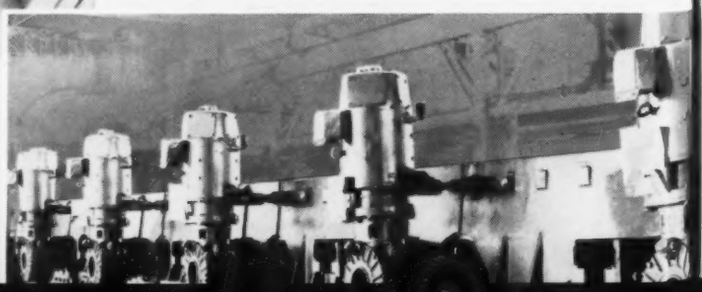


The 3 shear gauges were designed with pneumatic back-up cylinders to absorb impact. Note vernier allowing settings to ⅛ inch.

A major feature of the new Western Gear-designed shear table, pictured below (in two views) prior to shipment, is the use of 27 individual shaft-mounted gearmotors to drive each of the conveyor rollers, mounted vertically for ease of maintenance. Each unit can be replaced in minutes, sharply reducing downtime.





You can spot 40 TONS—

OR CRACK A WALNUT

WITH EC&M STATA CONTROL

Now it can be done with precision by AC! EC&M's STATA Hoist Control gives the finest electrically controlled speed regulation ever attained. Regardless of crane load, the operator can release the brake and hold any load stationary. Also, he has infinite operating speeds between standstill and full load motor speed for both hoisting and lowering. EC&M STATA Hoist Control provides these important benefits:

Fast response lets an operator change directions quickly, permits the hook to respond rapidly to master switch movements

No mechanical or electrical load brakes to mount or maintain

Fewer trolley (collector) bars than with any other stepless system

Fail-safe feedback circuitry removes power and sets brake if an open circuit occurs

Overhoisting protection with standard power-type (Youngstown) limit stop—no additional equipment to lower down after limit switch trips

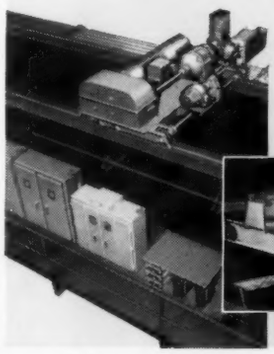
Simplified maintenance—the static components, enclosed in sub-assemblies, are more reliable, more easily understood and provide convenient inspection or test points

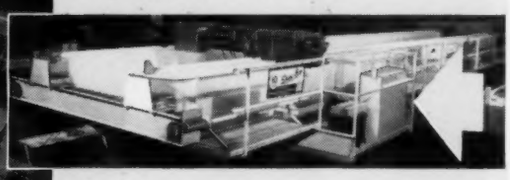
Float control, actuated by a push button in the master switch handle, permits standstill with the brake released, also provides creeping speeds, up or down.

Front-connected control panels facilitate mounting, permit rapid testing or inspection. Full motor protection built into each panel

When buying cranes or revamping existing ones, investigate EC&M STATA Control.

40-ton crane in midwestern heavy-metal processing plant, recently equipped with EC&M STATA Hoist Control





10-ton cranes on erection floors of Whiting Corporation *(left)* and Shaw-Box *(below)* with EC&M STATA Hoist Controllers, mounted and wired

Write **FOR COMPLETE FACTS** · *Ask for Bulletin 6401—Square D Company, EC&M Division, 4500 Lee Road, Cleveland 28, Ohio*

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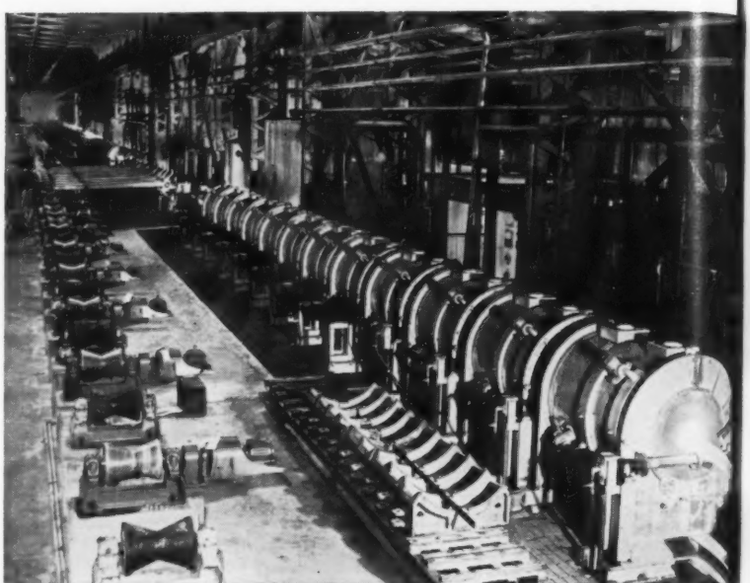
wherever electricity is distributed and controlled

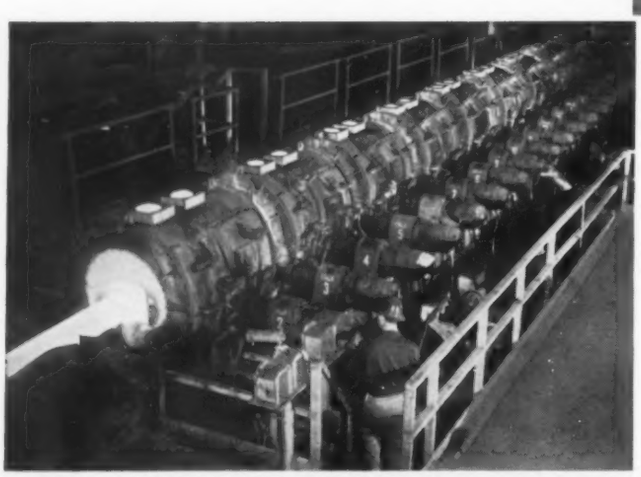
6120

NEW SLANTS ON HEAT PROCESSING FROM SELAS

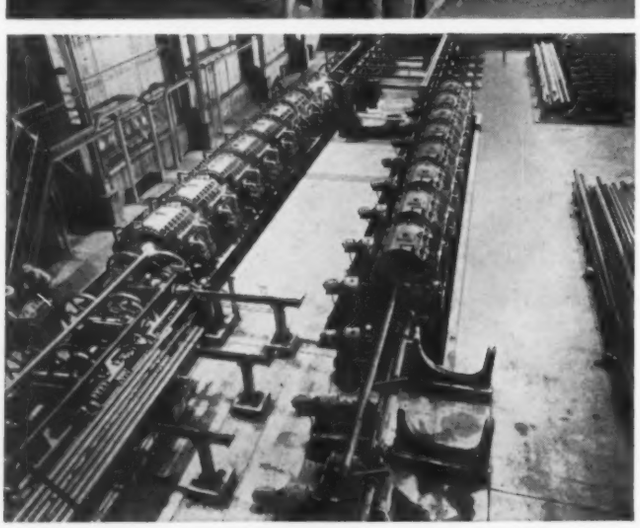
Here's how the Steel Industry relies



TUBING... *is normalized and, if required, stretch-reduced in this Selas barrel-furnace line. After forming and welding, the tubing is conveyed through a 48-barrel normalizing line with exit temperature approximately 1650° F. Stretch-mill product proceeds through 12 additional* GRADIATION® *furnaces which heat tubing to 1800°-1850° F. Entire process is automated, with line speeds matching mill speeds.*



BLOOM REHEATING *"on the fly," at rates of 198 tons per hour is accomplished in this continuous Selas barrel-furnace line. Reheating time of* only 3 minutes *reduces scale, amounting to a saving of 3 tons of steel per hour. Automated handling saved enough to pay for equipment in first 1½ months! Occupying floor area only 63' x 11', this continuous furnace assures uniform rolling temperature within each bloom and from piece to piece.*



SHORT-CYCLE HEATING *of seamless tubing for oil-country application is a typical cost-saving operation for Selas barrel-furnace lines. This overall view shows hardening (left) and tempering (right) lines, with automatic transfer between these treatments. Eight barrels per line. Advantages include: uniform properties throughout, negligible scale, reduced floor space requirements, and high degree of controllability.*

on Selas barrel-furnace lines

The installations on these pages graphically demonstrate how the steel industry relies on Selas barrel-furnaces to

- cut operating costs
- increase production rates
- reduce handling and labor requirements
- save valuable floor space
- improve product quality

Specifically designed and custom-built to meet individual production requirements and job specifications, Selas barrel-furnace lines employ time-proven standardized engineering features for long-time operating dependability and minimum initial investment. Acceptance? 446 Selas barrel-furnaces are at work in 49 separate heat treating lines for a variety of continuous applications including annealing stainless bars and tubing, heating billets for piercing, reheating pierced tubes for sizing, hardening and tempering oil country alloy and carbon tubing, etc. What's more, 96 additional units are now in various stages of construction.

At your convenience . . . without cost or obligation to you . . . a Selas field engineer would welcome the opportunity to survey your needs. For this personal service contact our Furnace Steel Mill Division, Dresher.

SELAS CORPORATION OF AMERICA
410 Dreshertown Road, Dresher, Pa.

EUROPEAN SUBSIDIARY: Selas Corporation of America, European Div., S.A., Pregny, Geneva, Switzerland. INTERNATIONAL AFFILIATES: AUSTRALIA—Major Furnace and Combustion Engineers Pty, Ltd., Melbourne; FRANCE—Societe Exploitation de Produits Industriels, Paris; JAPAN—International Machine Co., Ltd., Tokyo.

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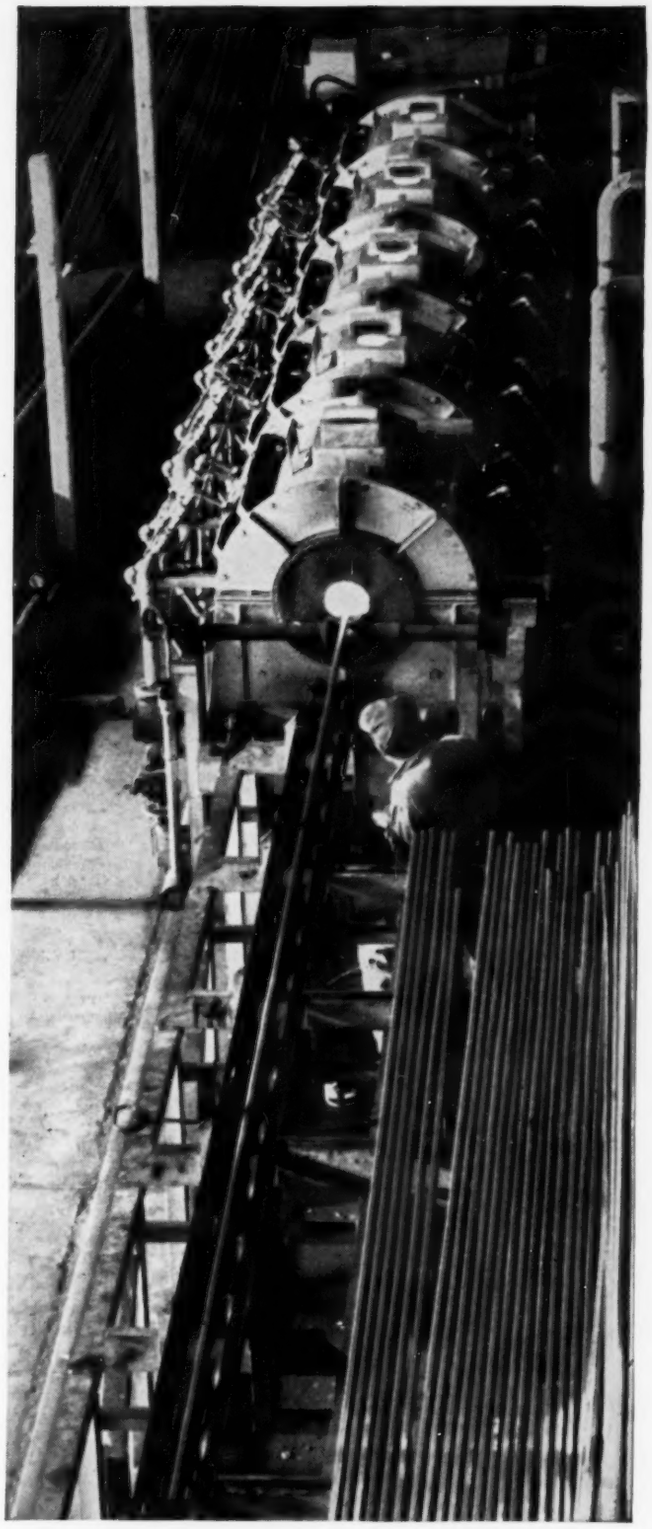
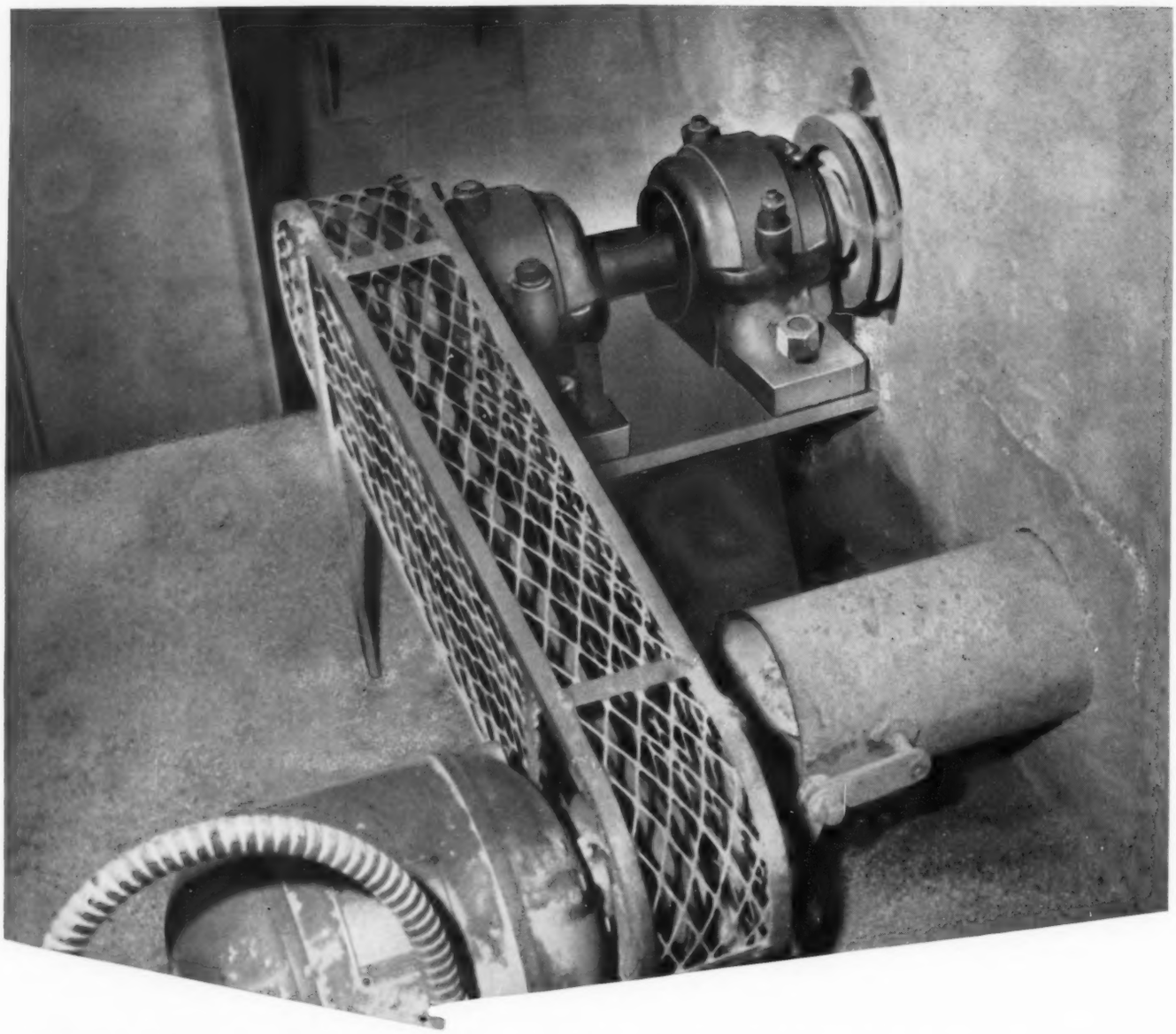
SELAS

HEAT AND FLUID PROCESSING ENGINEERS
DEVELOPMENT / DESIGN / CONSTRUCTION



STAINLESS STEEL *bars up to 5¼" cross-section and lengths to 30' are continuously annealed, and other grades normalized in this compact line of barrel-type furnaces.* DURADIANT® *burners heat uniformly at high thermal gradient without flame impingement on the work, resulting in minimum oxide formation. Annular ring water-spray quench cools work quickly and uniformly for maximum straightness in the annealed product.*



Galled and frozen shafts eliminated . . . a costly maintenance problem solved!

Twenty special, high temperature, recirculating fans installed on a furnace in a Missouri brick plant were a constant expense and source of trouble due to the failure of the water cooled, babbitted bearings.

Often, too, the shafts would gall and freeze in the bearing and shaft replacement was an expensive procedure.

Our Neiman Division bearing engineer suggested these bearings be replaced with anti-friction pillow blocks. Conversion cost was only $150 compared with $175 to repour the babbitted bearing. Another plus was the elimination of the water cooling towers. After three years of service, no bearing failures have occurred and maintenance problems are eliminated!

You may not make brick, but if you have any kind of bearing problem — we are ready to help you, day or night. Just call the branch nearest you.

Providing bearing service in the North ➤ **BEARINGS, INC.**

DELAWARE: Wilmington • **ILLINOIS:** Neiman Bearings Co., E. St. Louis • **INDIANA:** Fort Wayne • Indianapolis • Muncie • Terre Haute **MARYLAND:** Baltimore • **MISSOURI:** Neiman Bearings Co., St. Louis • **NEW JERSEY:** Camden • Newark • **NEW YORK:** Balanrol Corp., Buffalo • **OHIO:** Akron • Canton • Cincinnati • Cleveland • Columbus • Dayton • Elyria • Hamilton • Lima • Lockland • Mansfield Painesville • Toledo • Youngstown • Zanesville • **PENNSYLVANIA:** Erie • Johnstown • Philadelphia • Pittsburgh • Reading • York **WEST VIRGINIA:** Charleston • Huntington • Parkersburg • Wheeling

and

in the South ➤ **DIXIE BEARINGS, INC.**

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TURNKEY

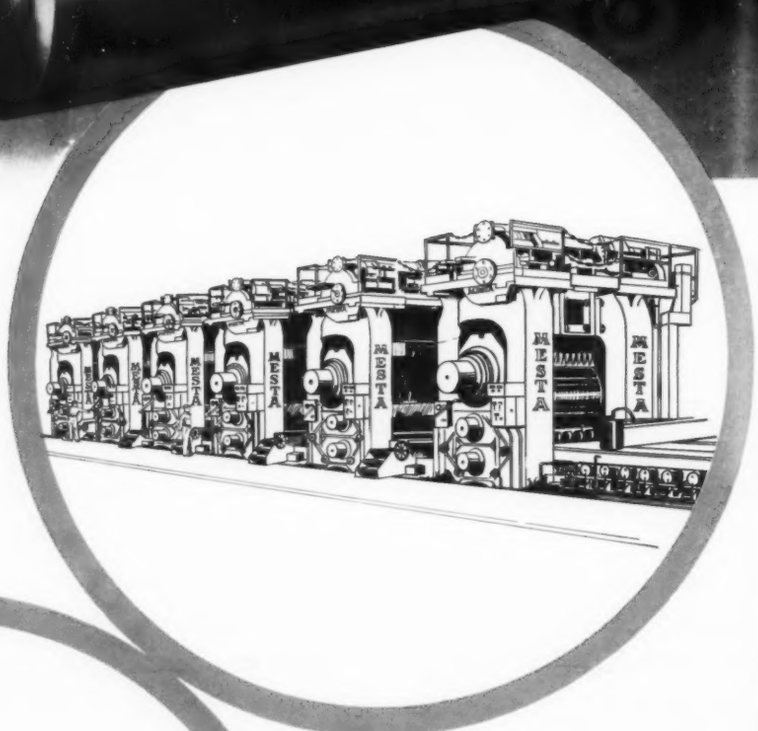
The design and construction approach that can cut time and costs on your new plant—and KE is a master at it!

Turnkey means that one, universally-competent architect-engineer-construction firm takes your new plant or expansion project, from initial concept to start-up—*literally from A to Z!* Project phases typically include feasibility studies and site selection, plant concept and preliminary engineering, detail design, procurement, construction, start-up and maintenance. You enjoy the proved efficiencies of single-contract responsibility, and free your own key people from time-consuming attention to the project. In Steel, in Minerals, in Power Generation, in the Nuclear field—Kaiser Engineers' experience in turnkey projects is widely recognized. A call from you will bring a specialist in your industry to summarize how KE has performed for others, can save money and valuable time for you.

KAISER ENGINEERS engineers-constructors Since 1914

Oakland, California—Chicago, New York, Pittsburgh, Washington, D.C., Accra, Buenos Aires, London, Montreal, New Delhi, Sydney, Vancouver, Zurich

MESTA ROLLS



For Quality and Tonnage...

Equip your Hot Strip Mills with:

- "Mesta Special" Alloy Steel Rolls
- Mesta Chrome-Moly Alloy Steel Rolls
- Mesta Nickel Grain Grade "R" Rolls
- Mesta "Duplex" Rolls
- Mesta Hardened Chill Rolls

Designers and Builders of Complete Steel Plants

MESTA MACHINE COMPANY

PITTSBURGH, PENNSYLVANIA

Personnel News...

J. Leonard Hough has been named chief engineer of Republic Steel Corp.'s Central Alloy Steel District. **E. W. Phillips,** who has been chief engineer in the Central District since 1941, will continue in the same capacity until January, when he will retire after 31 years with Republic. A veteran of more than 22 years in the steel industry, Mr. Hough was associated with U. S. Steel, Koppers Co. and Algoma Steel before joining Republic in 1955 as assistant chief engineer at the company's Youngstown steel plant. He was promoted to chief engineer in Youngstown in 1960.

Carter H. Gray was named superintendent of the continuous weld pipe mill at Kaiser Steel Corp.'s Fontana plant. Mr. Gray came to Kaiser Steel in 1948 as a pickler in the pipe galvanizing area. The same year he was appointed shift foreman in galvanizing and in 1950 became general foreman. He was named assistant superintendent in 1953, the position he held prior to his present appointment.

Albert J. Bradfield has been appointed assistant superintendent of The Colorado Fuel and Iron Corp.'s Pueblo plant Mechanical Department. Mr. Bradfield has been serving as general foreman for the Mechanical Department's assigned maintenance since July. He had worked previously as foreman of the seamless tube mill's mechanical unit, foreman of the rod mill's mechanical unit and assistant foreman for the mechanical units of the 10 and 40-in. mills and rod mill. He joined CF&I in 1946 as a machinist.

Charles E. Clark has been appointed superintendent and **Elwood J. Bowman,** assistant superintendent of the 98-in. cold strip mill at the Cleveland District plant of Republic Steel Corp. Mr. Clark succeeds **H. H. Chapin,** who has been transferred to the corporation's Southern District plant in Gadsden, Ala. Mr. Bowman, formerly general foreman of the cold strip mill, succeeds Mr. Clark in the assistant superintendent's post. Mr. Clark joined Republic as a tester at the company's Warren, Ohio, plant in 1936. He was transferred to the Massillon Enduro plant as a laboratory assistant in 1940. In 1947 he moved to Canton as a mill metallurgist, and in 1954 he was transferred to Cleveland as general foreman of the 98-in. cold strip mill Finishing Department and in 1958 was named assistant superintendent of the department. Mr. Bowman joined Republic's Cleveland plant in 1937. In 1952 he was promoted to turn foreman in the Tandem Rolling Department of the cold strip mill and became general foreman in 1955.

William T. Geiger was named superintendent, 110-in. rolling mill—30-in. hot strip mill, Alan Wood Steel Co. **Robert G. Leister** was named superintendent, hot strip finishing and cold strip mill, and **Elias E. Myers, Jr.,** has been appointed assistant superintendent, hot strip mill finishing. Mr. Geiger, who joined Alan Wood in 1952, has served as superintendent, hot strip finishing and cold strip mill since 1954. Mr. Leister has held various supervisory positions in the company since 1939. In 1954 he was named assistant superintendent, Hot Strip Finishing Department.

Louis J. Polman, Jr., was appointed superintendent of construction for The Youngstown Sheet and Tube Co.'s Indiana Harbor works. Mr. Polman previously was employed as project manager for the Charles W. Cole contracting firm engaged in construction work at Indiana Harbor works.

Jaye S. Gamble was named division superintendent of blast furnaces, open hearth and bessemer and rolling mills, National works, United States Steel Corp. His previous position, that of chief metallurgist, has been filled by **Walter A. Barres.** Mr. Gamble succeeds **J. P. Ely,** recently appointed assistant general superintendent at the plant. Mr. Gamble joined U. S. Steel at National works in 1936 as a metallurgical observer and student engineer. In 1942 he was advanced to supervisor, steel works observers and in 1948, supervisor, pipe mill metallurgists. Mr. Gamble was appointed assistant chief metallurgist in 1951 and in 1955, chief metallurgist. Mr. Barres had been serving as assistant chief metallurgist for National Tube Division in Pittsburgh since 1956. He joined U. S. Steel at National Tube's Lorain works, Ohio, in 1936 as a chemical analyst and student engineer. In 1940 he was transferred to Christy

J. L. HOUGH (left)
C. H. GRAY (center)
A. J. BRADFIELD (right)

HAROLD ELSPASS

M. L. KOCHEVAR

D. S. MYERS

B. B. FROST

Park works, Pa., as student engineer and metallurgical engineer. He was transferred to National works as metallurgical assistant in 1945, subsequently becoming staff metallurgist in 1948, supervisor, pipe mill metallurgists in 1951 and assistant chief metallurgist in 1955.

Harold Elspass has been appointed general mechanical foreman for the 10 and 14-in. mills and the merchant and angle finishing departments of The Colorado Fuel and Iron Corp.'s Pueblo plant. Mr. Elspass has been serving as foreman of the 14 and 25-in. mills since 1948. He had worked previously as general foreman of the finishing departments and as head millwright in the rail mill. He joined CF&I's Mechanical Department in 1920. **Mickey L. Kochevar** has been appointed assistant general mechanical foreman for the 10 and 14-in. mills and the merchant and angle finishing departments. He has been serving as assistant foreman for the 14 and 25-in. mills since 1948. He had worked previously as assistant foreman for the 25-in. mill and has held various positions in the 14-in. and the 25-in. mills. He joined CF&I in 1935 in the spike mill.

Donald S. Myers has been named vice president of Amsler Morton Co., a Textron subsidiary. Mr. Myers will be in charge of furnace sales to the steel industry. He was previously with the Surface Combustion Co.

B. B. Frost, sales manager of Arthur G. McKee & Co.'s Metals Division since 1955, has been named vice president of sales for the division. Mr. Frost joined McKee as a service engineer at the company's Cleveland headquarters in 1936. He became the sales engineer in 1946. He was employed in the Blast Furnace Department of Inland Steel Co. before joining McKee.

F. R. Kyle has been appointed assistant superintendent of the Open Hearth Department at Republic Steel Corp.'s Cleveland District plant. He succeeds **E. G. Kondas,** recently named general superintendent of Republic's Chicago District plant. Mr. Kyle joined Republic in 1955 as a junior melter in the Open Hearth Department at the Cleveland plant. He became a senior melter in 1956 and was appointed general foreman of the No. 2 open hearth shop in 1958.

John F. McCarthy has been appointed supperintendent of the Blooming and Hot Strip Mills Department at the Cleveland works of Jones & Laughlin Steel Corp. Mr. McCarthy comes to Cleveland from J&L's Aliquippa works where he has served for the past three years as assistant superintendent of blooming, hot strip and rolling mills. Prior to that, he was general foreman of the new 44-in. hot strip mill at the Aliquippa works during the mill's construction and during its early stages of operation from 1956 through 1958. Mr. McCarthy joined the Steel Co. of Canada as a hot strip mill rougher in 1937. He left in 1951 and has since held positions in hot strip rolling operations with USINOR of France from 1951 to 1952; Sollac of France, 1952 to 1954; Ougree Marihaye of Belgium, 1954 to 1955 and Australian Iron & Steel Co., 1955 to 1956.

Lynn H. Ransom has been appointed manager of purchases and raw materials of Republic Steel Corp. He succeeds **W. T. Adams** who died September 5. Mr. Ransom had been assistant manager of purchases for the past seven years. A veteran of 25 years of experience in various aspects of purchasing at Republic, he joined the company in 1936 in the mechanical section of the Purchasing Department. In 1945, he was named purchasing agent for the Truscon Division of Republic with headquarters in Youngstown, Ohio, and held this position until his promotion to assistant manager of purchases for the corporation in 1954.

H. Kimble Hicks has been appointed manager of the Philadelphia district office of Dravo Corp.'s Machinery Sales Department. Mr. Hicks, who joined Dravo in Philadelphia in 1938, has been manager of the department's Pittsburgh office since 1956. He was assistant manager of the Philadelphia office for seven years before coming to Pittsburgh.

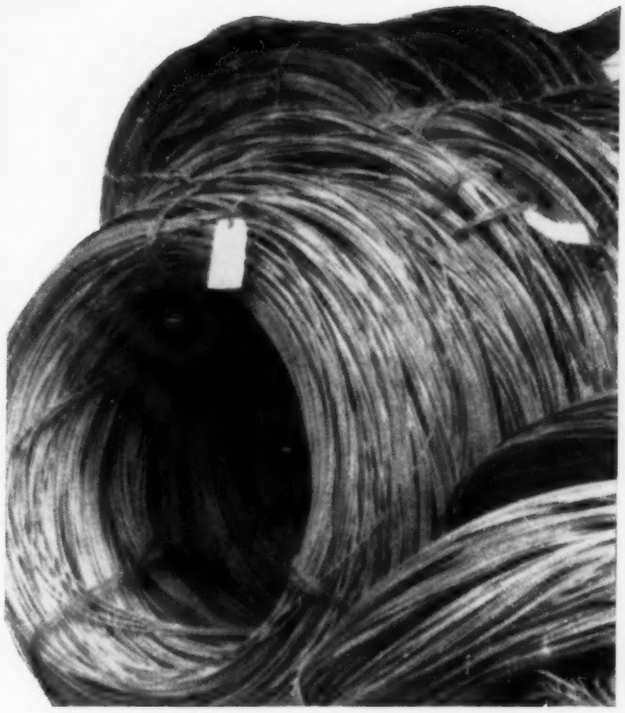
Paul L. Daley has been appointed assistant chief metallurgist for U. S. Steel Corp.'s National Tube Division. Mr. Daley had been manager of National Tube's research laboratory. Succeeding him as manager of the research laboratory is **Raymond C. Bowden, Jr.,** formerly corrosion engineer. Mr. Daley began his business career at National Tube's Ellwood works, Ellwood City, Pa., as an apprentice engineer. He served in various capacities in the metallurgical department and was made chief metallurgist there in 1942. Mr. Bowden began his business career with Jones & Laughlin Steel Corp. and joined National Tube in 1948 as a chemist.

(Please turn to page 245)

Operation: Descaling

(One of a series)

Drawn and annealed wire descaled up to 800 feet per minute



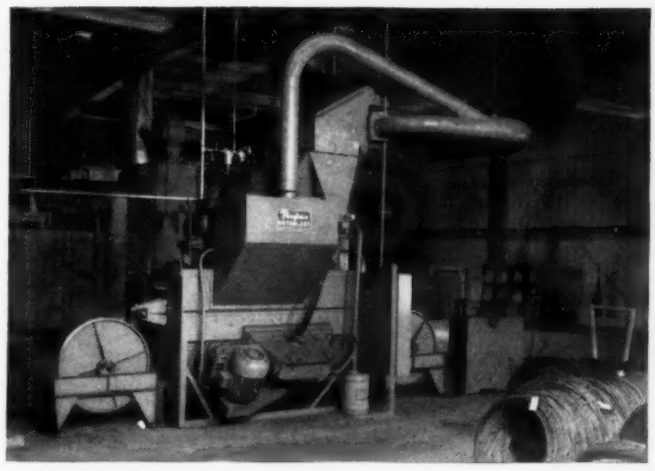
Hot rolled rod descaled at 200-600 feet per minute

These figures speak for themselves!

Compare these speeds with your own descaling performance. Then consider this: fast descaling time is only one of many reasons why Pangborn Rotoblast cuts your costs.

Here are some other specifics: Rotoblast eliminates loss of virgin metal . . . ends acid disposal problems . . . requires less space . . . reduces original investment by as much as 70% over pickling equipment. Rotoblast descaling equipment goes to work at the touch of a button. Because it is a dry process, it is absolutely non-toxic, an important aid to employee morale. Rotoblasting gives an improved surface for application of lubricant.

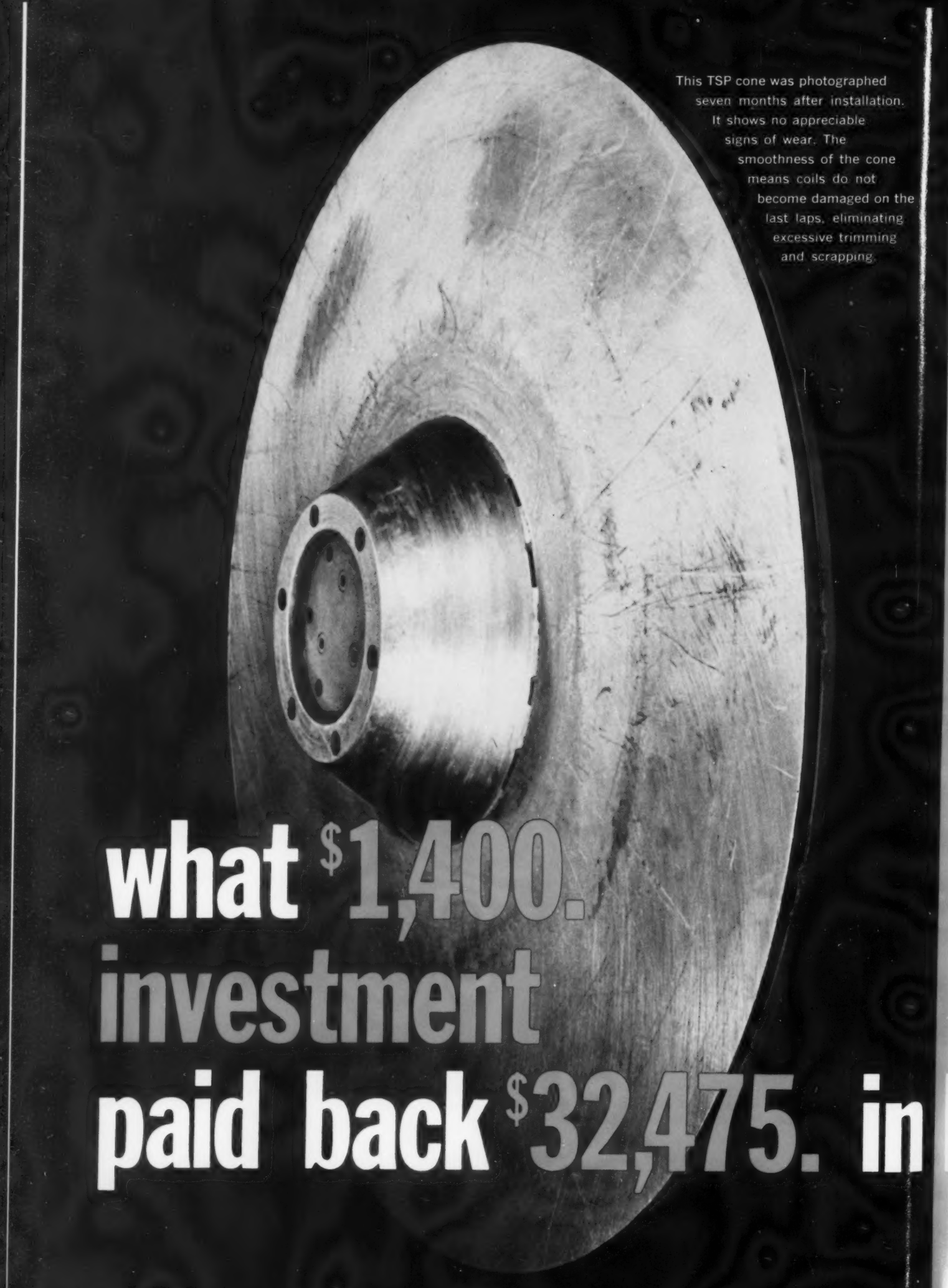
You save money other ways, too. You can maintain Rotoblast more easily. Because Rotoblast Cabinets are fully lined with wear plates, you never have to replace the cabinets themselves. All three wheels of the Rotoblast units assembly are fully exposed and easily accessible—not locked up inside the equipment. Overall result: lower operating costs, lower maintenance costs.



Pangborn

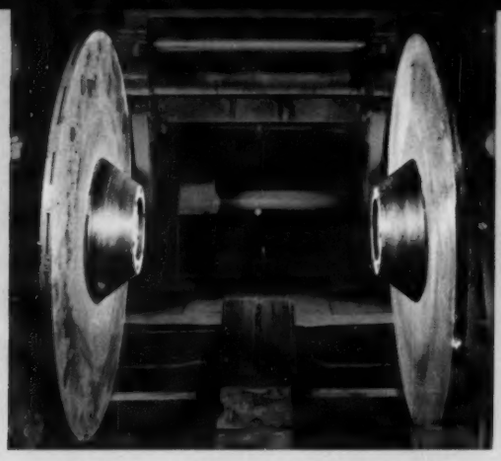
OF HAGERSTOWN

For more detailed information, write: PANGBORN CORPORATION, 4400 Pangborn Blvd., Hagerstown, Md.; Pangborn Canada, Ltd., 47 Shaft Rd., Toronto (Rexdale), Canada—*Manufacturers of Blast Cleaning, Vibratory Finishing, Dust Control Equipment; Rotoblast® Steel Shot and Grit®.*

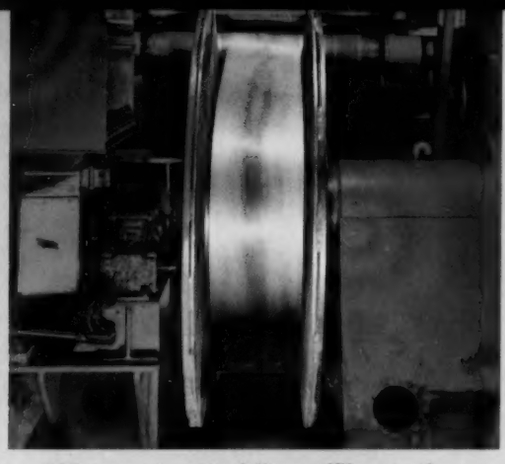


This TSP cone was photographed seven months after installation. It shows no appreciable signs of wear. The smoothness of the cone means coils do not become damaged on the last laps, eliminating excessive trimming and scrapping.

what $1,400. investment paid back $32,475. in



TSP cones show no wear after seven months service.



TSP cones in actual "pay off" operation showing fine condition of last laps of coil.

As a result of continually scrapping cast steel cones after only four weeks service, a large Eastern steel producer* invested $1400. in two sets of "Tool Steel Process" hardened steel cones, or $400. more than cast steel cones. Here are the results of that decision.

First set of TSP cones lasted 16½ months on drive side (16½ to 1 wear ratio over competitive cones) and 43 months on idler side (43 to 1 wear ratio over competitive cones).

Competitive cones cost	$ 500.
TSP cones cost	$ 700.
Replacement cost savings based on comparative wear ratios	$15,850.

Second set of TSP cones lasted 47 months (47 to 1 wear ratio over competitive cones) and 20½ months on idler side (20½ to 1 wear ratio over competitive cones).

Competitive cones cost	$ 500.
TSP cones cost	$ 700.
Replacement cost savings based on comparative wear ratios	$16,625.
Total Investment	$ 1,400.
Total Replacement Cost Savings	$32,475.

TSP steel cones do a superior job because their special hardening maintains a smooth surface. Coils remain undamaged when paying off right to the last lap. In addition to their long wearing qualities. TSP cones deliver a finer product. A special hardening process gives a file hard surface that maintains a smooth surface. Coils remain undamaged.

The phenomenally long wearing qualities of TSP cones over competitive cones are a result of a special hardening process which gives each cone a file hard surface to the full depth of permissible wear. This file hard surface is extra smooth and stays that way over the life of the cone. Because of this superior smoothness, coils remain undamaged right through the last lap.

For complete information on TSP cones and many other TSP hardened products for the steel industry, write today.

The standard of quality since 1909 for gears, pinions, rolls, wheels and other hardened products.

MEMBER OF AGMA

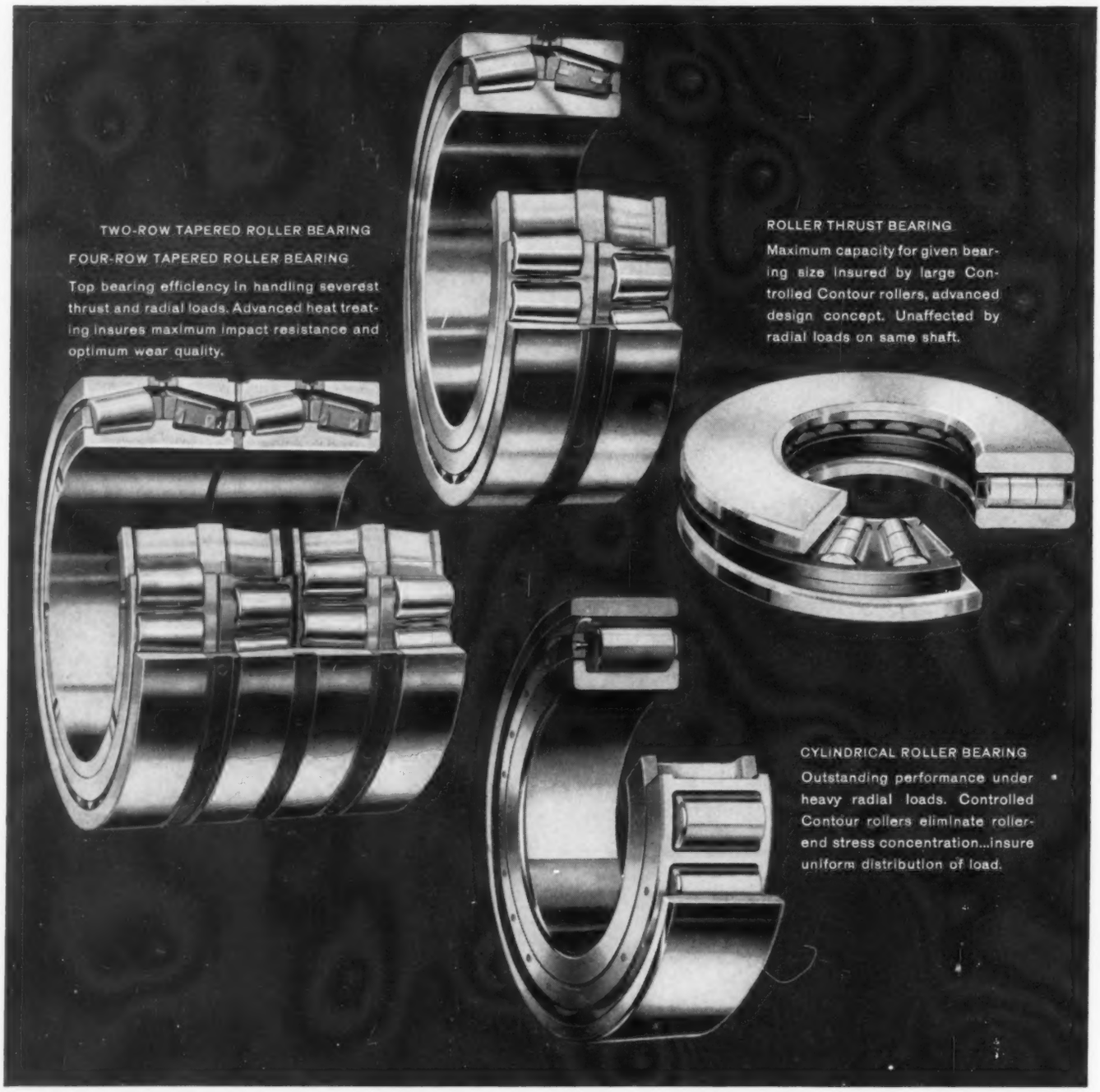
THE TOOL STEEL GEAR & PINION COMPANY

CINCINNATI / OHIO / USA

* name on request

n less than six years?

TORRINGTON


TWO-ROW TAPERED ROLLER BEARING
FOUR-ROW TAPERED ROLLER BEARING
Top bearing efficiency in handling severest thrust and radial loads. Advanced heat treating insures maximum impact resistance and optimum wear quality.
ROLLER THRUST BEARING
Maximum capacity for given bearing size insured by large Controlled Contour rollers, advanced design concept. Unaffected by radial loads on same shaft.
CYLINDRICAL ROLLER BEARING
Outstanding performance under heavy radial loads. Controlled Contour rollers eliminate roller-end stress concentration...insure uniform distribution of load.

TORRINGTON PRECISION...RIGHT WHERE YOU NEED IT!

Whatever the type of Torrington bearing best suited to your needs, you can be sure of one thing...Torrington precision.

Precision is a byword at Torrington. It represents basic Torrington thinking on every aspect of design, material, engineering and performance.

To you, it means absolute surety in your bearing choice... absolute dependability in every bearing you buy. Remember that Torrington makes every basic type of anti-friction bearing...can advise you impartially on the one that's right for you. If you have a bearing problem, call or write us today.

progress through precision

THE TORRINGTON COMPANY

TORRINGTON BEARINGS

South Bend 21, Indiana, Torrington, Conn.

(*Continued from page 240*)

Ray J. Stanish has been appointed general sales manager for TRW Computers Co., a division of Thompson Ramo Wooldridge Inc. Prior to his promotion, Mr. Stanish was central regional sales manager in charge of TRW Computers' Chicago office. Previously he was chief engineer, TRW's Replacement Division.

Charles J. Ellis and **Harry P. Gough** have been elected regional vice presidents of the General Electric Co. for the Southeastern and Western regions respectively. Mr. Ellis succeeds **Carter L. Redd,** who, until his retirement from the company on January 1, 1962, will be consultant to Mr. Ellis. Mr. Gough succeeds **Clarence C. Walker,** who, until his retirement on November 1, 1961, will be consultant to Mr. Gough.

L. O. Witzenburg has been promoted to general sales manager of both the Farval Division and Cleveland Worm & Gear Division, Eaton Manufacturing Co. At the same time, **E. J. Gesdorf** and **D. W. Leader** were named sales managers of Farval and Cleveland Worm & Gear respectively. Mr. Witzenburg served as general manager and vice president of sales of both Cleveland Worm & Gear and Farval before they were acquired by Eaton. Mr. Gesdorf has been chief application engineer of Farval the last seven years. Mr. Leader was formerly head of the Variable Speed Drive Department of Cleveland Worm & Gear. Mr. Leader will be assisted by **Maurice J. Losh,** who has been promoted to Cleveland Worm & Gear's assistant sales manager. He has been with the division for 11 years, the last seven as assistant to **R. E. Dittoe,** recently retired after 42 years of service.

John R. Dingle has been appointed assistant manager of the Cleveland Worm & Gear Division, Eaton Manufacturing Co. Mr. Dingle has spent his entire business life with the division, beginning in 1946 in the Engineering Department. He has been Cleveland Worm & Gear's works manager for the past 18 months.

T. J. Simendinger has been named hoisting equipment product sales manager, Yale Materials Handling Division, The Yale & Towne Manufacturing Co. In the newly-created position, Mr. Simendinger is in charge of the administration of the Hoisting Equipment Sales Headquarters Department. He had been serving as district sales manager for eastern Pennsylvania, southern New Jersey, Delaware and Maryland since 1956. He joined the company in 1951 and had previously worked as an assistant to the hoist sales manager and as a district salesman in eastern Pennsylvania.

Edgar B. Mancke, formerly associate director of research, chemical engineering, has been named director, project evaluation, Research Department, Bethlehem Steel Co. **Frank M. Temmel,** formerly assistant director of research, chemical engineering, has been named associate director, succeeding Mr. Mancke.

Augustus D. Lagomarsino has been appointed to the position of purchasing agent, Alan Wood Steel Co. He was most recently general manager, customer services.

R. B. Murphy has been appointed district manager of the Chicago, Ill., sales division of The Wapakoneta Machine Co.

Carl T. Zimmerman, formerly staff engineer—automation with American Steel and Wire Division, United States Steel Corp., has established a consulting service in the field of automation. It is located at 24437 Hazelmere Road, Cleveland 22, Ohio.

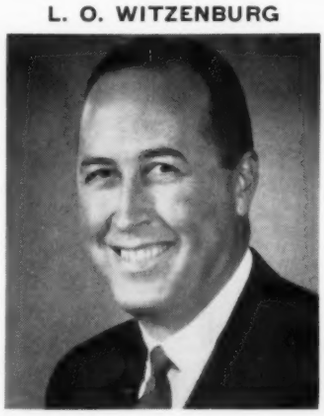
W. M. Kelly has been appointed manager—technical operations for Union Carbide Metals Co., division of Union Carbide Corp. Prior to his appointment, Mr. Kelly had been assistant technical director—alloys operations since 1959. Before that he had been plant metallurgist for the Niagara Falls, N. Y., plant. He joined Union Carbide Metals in Niagara Falls in 1945.

John J. Bradfield was named to head the new Cleveland, Ohio, office of the Pennsylvania Crusher Division of Bath Iron Works Corp. Mr. Bradfield joined Pennsylvania Crusher in 1935.

R. T. Cowan, former Detroit, Mich., manager, Bailey Meter Co., has been appointed manager of the Chicago, Ill., district. **J. A. Lucas,** former Milwaukee, Wis., manager, has been named manager of the Detroit district and **R. E. Byers,** former Memphis, Tenn., manager, has been appointed manager of the Milwaukee district.

Robert W. Engelbert has been appointed assistant chief engineer for the Cleveland District of Republic

L. O. WITZENBURG



E. J. GESDORF

D. W. LEADER

J. R. DINGLE

H. J. BOLWELL

J. W. THORNTON

NORMAN BLOCK

HOWARD STRANDBERG

Steel Corp. He succeeds **R. T. Richmond,** recently named chief engineer at Republic's Youngstown District plant. Mr. Engelbert joined Republic as a field engineer for the Buffalo District plant in 1949. He was named assistant chief engineer at Buffalo in 1953, and, in 1959, was transferred to Republic's Southern District plant at Gadsden, Ala., where he served in the same capacity.

Harry J. Bolwell was elected vice president of Midland-Ross Corp. and general manager of the company's Surface Combustion Division. Mr. Bolwell previously was general manager of the Chattanooga Division of Combustion Engineering, Inc. He succeeds **Eugene P. Heiles,** who will retire from the company early next year. Until his retirement he will continue as a vice president of Midland-Ross and will serve in an advisory capacity to the Surface Combustion and other divisions of Midland-Ross. Mr. Bolwell joined Combustion Engineering in 1954 as assistant chief engineer of the company's Nuclear Division. He was elevated to manager of the Nuclear Components Department in 1956 and was named general manager of the Chattanooga Division in 1958. In the latter capacity, he was responsible for the operations of the division's five manufacturing plants including the Nuclear Components Department.

John W. Thornton has been elected vice president and general manager of the Industrial Division of Joy Manufacturing Co. He formerly was vice president, marketing. Mr. Thornton joined Joy in 1957.

Norman Block has been appointed director of engineering and research for Western Precipitation Division of Joy Manufacturing Co. Mr. Block was associated with the Foster Wheeler Corp. in New York for 13 years, where he was director of materials research, and most recently director of quality control.

Howard Strandberg has been appointed assistant general sales manager of the Refractories Division of H. K. Porter Co., Inc. Prior to his appointment, Mr. Strandberg was the division's New York district sales manager. He previously was executive vice president in charge of operations for Seaboard Refractories Co.

Charles R. Heilig was appointed manager of furnace products sales, Basic Incorporated. **Thomas D. Hess** succeeds Mr. Heilig as central district sales manager. Prior to joining Basic in 1944, Mr. Heilig was associated with Laclede Steel Co., where he held the posts of melter, furnace operator and open hearth superintendent. Mr. Hess was formerly assistant sales manager of the central district. Before coming with Basic he was superintendent of No. 1 open hearth shop at the Indiana Harbor works of The Youngstown Sheet and Tube Co. with whom he was associated for 12 years. Formerly he was assistant superintendent with Crucible Steel Co. of America at Midland, Pa., and a melter at Bethlehem Steel Co.'s Steelton, Pa., works.

Paul E. Zeits has been appointed district manager of the Pittsburgh Sales Division of The Wapakoneta Machine Co. He will be assisted by **Norman D. Carpenter.**

Philip S. Hill has been named president of Hyster Co., succeeding **Ernest G. Swigert,** who was appointed chairman of the board of directors and chief executive officer of the company. At the same time **Harvey N. Black** was named as senior vice president.

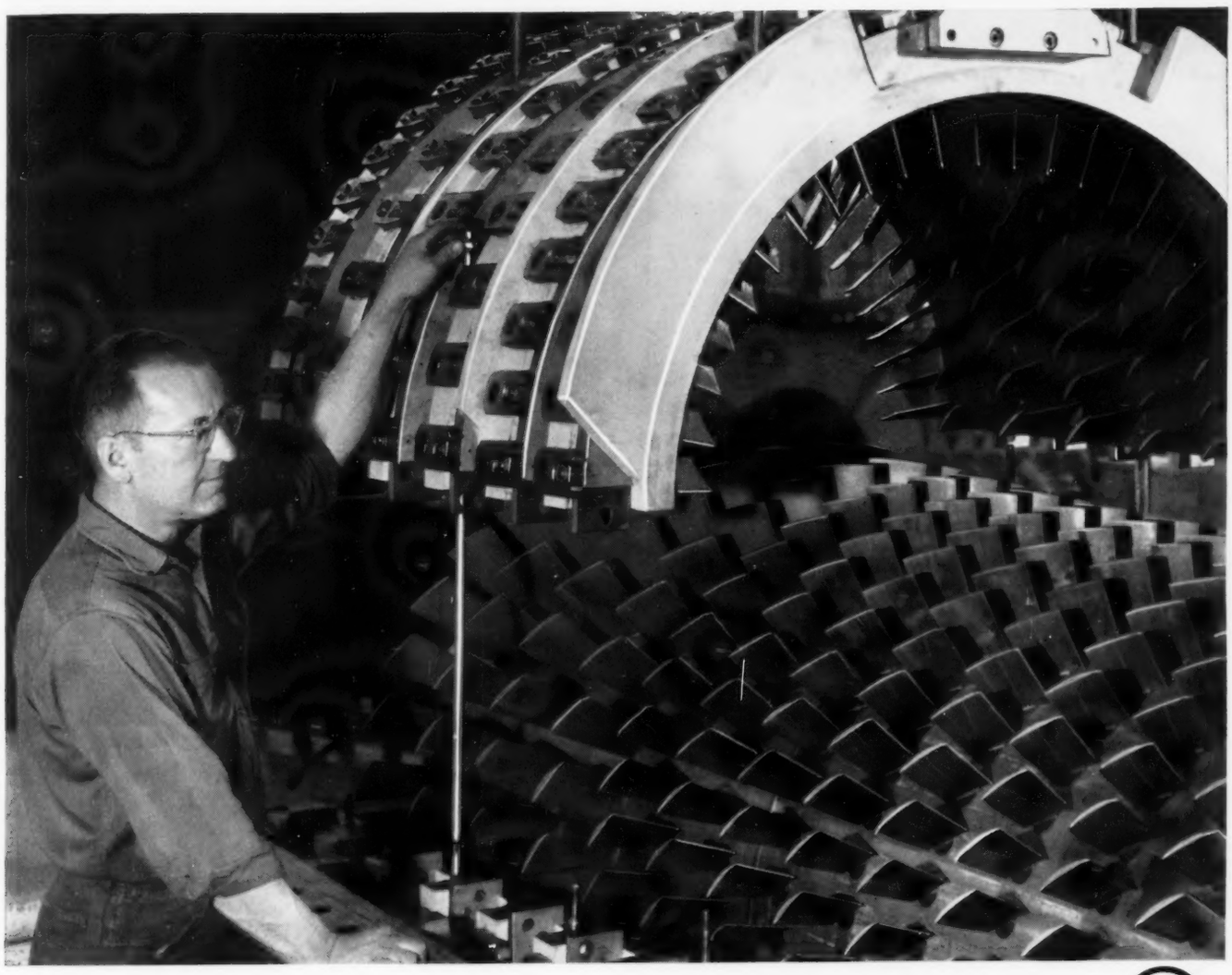
J. E. Wilson has been named general sales manager of Erie Foundry Co. He joins Erie Foundry following service in domestic locomotive sales with the General Electric Co.

John W. McReynolds was named manager—industrial truck sales and **Edwin F. Neuman,** manager of service for Automatic Transportation Co., a Division of the Yale and Towne Manufacturing Co. Mr. McReynolds will direct all sales activities on industrial trucks for

J. W. McREYNOLDS

E. F. NEUMAN

ALLIS-CHALMERS

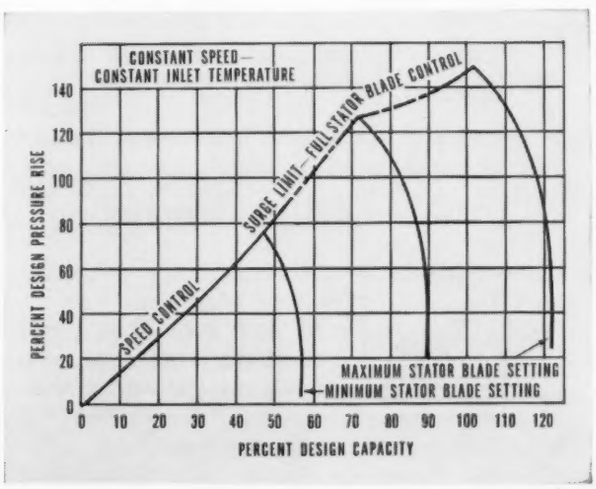


New Adjustable Blade Axial Compressor for Blast Furnace Duty at USS

world's first; who's next?

What you're looking at is the world's first adjustable blade axial compressor designed for blast furnace duty. This 50-psig, 165,000-cfm machine is to be installed at U. S. Steel's Edgar Thomson Works in the Fall. No other unit can do what this one does . . . or can save what it saves.

Should your company be the next to install one, you would benefit three ways. *You'd save space.* The efficiency of this compressor is such that its diameter and weight are *half* that of equivalent centrifugals. *You'd reduce steam requirements.* Efficiency, again. This axial uses at least 10% less steam than other types of compressors. *And you'd meet a broader-than-ever range of operating demands.* Adjustable stator blades can vary capacity instantly . . . while the machine operates at constant speed. The graph tells the full story.



Ask your A-C representative to analyze your compressor requirements. Or write **Allis-Chalmers,** Industrial Equipment Division, Milwaukee 1, Wisconsin. A-1535

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Men like National's metallurgist Joe Marsalka see to that. Before your roll is born, National helps select the proper composition, grade and hardness. As it is being produced, our metallurgists carefully control chill locations, pouring procedures and heat treatment. When the roll is "full-grown" ultra-sonic testing equipment checks its internal soundness making sure your roll is ready for the tough life ahead. Even after your roll is shipped, National keeps in touch with its performance in your stand. This intimate knowledge of roll life is one reason we are able to consistently produce quality steel, iron and nodular iron rolls. It's a big reason why... NATIONAL'S THE GROWING NAME IN ROLLS.

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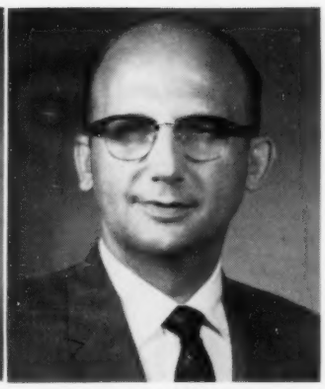
GENERAL STEEL INDUSTRIES, INC., Avonmore, Pennsylvania
General Steel Industries, Inc., General Offices: Granite City, Ill. Plants: Granite City, Ill., Eddystone, Pa., Avonmore, Pa.
Subsidiary: St. Louis Car Company, St. Louis, Mo.

W. J. KERR



C. J. LANTZ

the United States and Canada. Mr. Neuman is responsible for formulating service and parts activities for all division branches and dealerships in the United States and Canada.

William J. Kerr was named vice president, development, The Yoder Co. In his new capacity. Mr. Kerr will be responsible for product research and development programs of the company. Mr. Kerr has served as vice-president—production since 1946. At the same time, **Charles J. Lantz** was named director of production.

Leo Martin, retiring chief engineer for Western Gear Corp., has been named to a new post as special consultant for the firm. He is succeeded in the post of chief engineer by **Raymond W. Whelan,** former sales manager at the firm's Belmont, Calif., plant.

Richard W. Vollmer has been appointed assistant to the president of Strategic Materials Corp. Mr. Vollmer has been associated with the Koppers Co. for the past 20 years where he most recently was manager of the Direct Reduction Sales Department.

Jim Gillis was named general manager—operations, mill sales, The Ohio Knife Co. Mr. Gillis was formerly district manager in charge of the Pittsburgh-Cleveland area. The Pittsburgh and Cleveland sales offices will continue to be under his jurisdiction with **Don O'Connor** in the Pittsburgh office and **Charles F. Rankin** in the Cleveland office.

A. W. Baker has been appointed superintendent of the new Welded Tubing Department, Shapeweld Division of Solar Steel Corp., Union, N. J. Prior to his appointment, Mr. Baker was assistant superintendent of the Welding Mill Department of Jones & Laughlin's Electricweld Tube Division in Oil City, Pa.

Alex J. Szabo has been appointed sales engineer, Cleveland district, Pangborn Corp. Mr. Szabo worked as a methods engineer at Ford Motor Co., then joined Pangborn in 1956 as sales engineer in Detroit. For the past year he has been supervisor, Vibratory Finishing Division in the Hagerstown, Md., plant.

Preston F. Ryan was appointed manager of Wagner Electric Corp.'s Electrical Apparatus Division, St. Louis sales office. At the same time **Herbert P. Pillisch** was appointed manager of the Indianapolis office. Each will supervise sales of electric motors, transformers and industrial brake products in his area. Mr. Ryan joined Wagner in 1936. He has served in various sales capacities, including six years in the factory Motor Sales Department, and since 1946, as a sales engineer in the St. Louis territory. Mr. Pillisch joined Wagner in 1954 and has been a sales engineer in the St. Louis territory since 1955.

Ronald E. Towns, Jr., has been named superintendent of The Youngstown Sheet and Tube Co.'s electric weld tube mill at the Brier Hill plant, Youngstown, Ohio. He succeeds **Clifton R. Coburn,** who has retired after 35 years with the company. General welding foreman since 1958, Mr. Towns joined Youngstown in 1946 as a lineman helper. Mr. Coburn had been superintendent of the electric weld tube mill since 1945.

Donald P. Cairns, formerly a project engineer at Granite City Steel Co., has been promoted to plant engineer of the company's Blast Furnace Department succeeding **Harold L. Lewis,** who has retired.

Louis J. Geiger has been appointed manager of marketing for General Electric Co.'s Process Computer Section, Phoenix, Ariz. As marketing manager of the recently formed product section, he will have broad over-all responsibility for marketing research, product planning, sales and promotion for the company's process computers. Mr. Geiger has been manager of starter and accessories sales for the company's Industry Control Department at Salem, Va., since 1955. After six months on the company test course as a student engineer, Mr. Geiger spent a year as a junior engineer and project engineer with the former Fan and Sunlamp Department at Bridgeport, Conn. In 1946, he was named a product engineer with the Industry Control Department. He became a proposition engineer with the department's sales group in 1948, was made leader of its starter sales group in 1951 and was appointed manager of starters sales in 1953. In 1954 he was appointed manager of the department's Milwaukee, Wis., sales office, and the following year was recalled to the department's headquarters to take the managerial position he has held to the present time.

John E. Brinkmann has been appointed general superintendent, electrical departments, Allis-Chalmers Manufacturing Co.'s West Allis works Industries Group. He succeeds **William C. Krecklow,** who becomes a consultant after almost 50 years of manufacturing experience with the company. Mr. Brinkmann joined Allis-Chalmers in 1942 and had been manager of the product inventory and scheduling section. Prior to that he was successively assistant superintendent and superintendent of production scheduling. Mr. Krecklow has been associated with Allis-Chalmers Manufacturing Department since 1912. He had been manager of the Industries Group's Production Control Department for 12 years prior to becoming general superintendent of the electrical departments in 1959.

C. J. Langley was named manager of Air Reduction Sales Co.'s Philadelphia district. He succeeds **R. H. Merriman** to the post. Mr. Langley joined Airco in 1946 as a member of the General Technical Department in New York. Three years later he was transferred to the Philadelphia district where he served as a engineering service representative. Transferred to the Boston district in 1953, he was appointed supervisor-

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End Product is longer life and lower maintenance for heat-resistant parts . . . radiant tubes, furnace rolls, blowpipes, gas generators and other tubular or tubular-section components.

Supertherm* is a 26% Cr—35% Ni alloy strengthened and stabilized with cobalt and tungsten. Supertherm* has proved its capability within the 1800-2300° F range and under very severe heat-cycling conditions. In many cases, the alloy has extended service life two to three times over previous operations.

The uniformity, density, quality advantages of centrifugal casting are assured in full at Electro-Alloys, recognized as having one of the finest centrifugal-cast facilities in the country.

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AMERICAN Brake Shoe COMPANY

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technical sales and later became assistant manager-sales for that district. Mr. Langley returned to the Philadelphia district last year to become assistant district manager—a position he held until his recent promotion.

John G. Munson, Jr., has been appointed assistant to administrative vice president—production of United States Steel Corp. Mr. Munson who has been general superintendent of United States Steel's Fairfield Coke & Chemical works, Tennessee Coal & Iron Division, will also serve as chairman of the corporation's operating committee for coke and chemical products, succeeding **H. W. Seyler,** who is retiring after 43 years of service. Mr. Munson joined the Tennessee Coal & Iron Division in 1953 as staff assistant in the manufacturing division, serving subsequently in a similar capacity in the office of vice president—operations. In 1956, he was made division superintendent of mills, Fairfield Steel works, and in 1958, he was advanced to the position from which he has just been promoted. Mr. Seyler started to work as an analyst at the corporation's Clairton works in 1918. The following year he became a chemist. He was made assistant chief chemist in 1922 and chief chemist in 1926. Appointed assistant vice president—coal chemical sales in 1936, he was transferred to New York. In 1937 he returned to Clairton as assistant general superintendent and in 1944, he advanced to general superintendent. In 1955 Mr. Seyler was transferred to the corporation's Pittsburgh headquarters where he co-ordinated various phases of coal chemical operations, becoming assistant to administrative vice president in 1958.

Albert W. Gudal, former purchasing agent for Lukens Steel Co., has joined Koppers de Venezuela, C.A., a subsidiary of Koppers Co., Inc. Mr. Gudal will be advisory manager of purchasing for the Orinoco steel plant of Corporacion de Venezolana de Guayana, a Venezuelan steel firm with which Koppers has a long-term management advisory contract. He will assist in the purchasing activities relative to the steel operations of the corporation. Mr. Gudal joined Armco Steel Corp. in 1936. In 1948, he joined Lukens as supervisor of planning and controls and was appointed purchasing agent in 1958.

Obituaries

William T. Adams, vice president, manager of purchases and raw materials of Republic Steel Corp., died September 5. He was 61. Mr. Adams had joined United Alloy Steel Co., a predecessor company of Republic, in 1920 in Canton, Ohio, and was manager of claims when he left the company in 1926 to become sales manager of the Moock Electrical Supply Co. Seven years later he returned to Republic as chief electrical buyer and, in 1945, became general purchasing agent. In 1954, he was named manager of purchases and raw materials.

William C. Siegrist, formerly vice president and director of Treadwell Engineering Co. of Easton, Pa., died April 21, 1961. Mr. Siegrist was connected with the Chicago office of Treadwell and had been a member of AISE for many years.

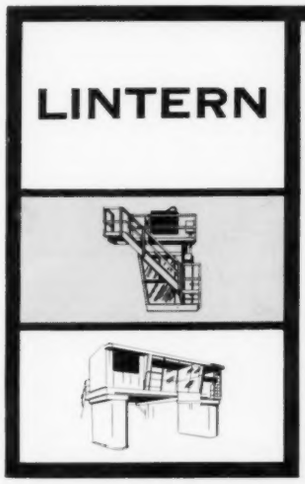
Ferdinand W. Dohring, 62, vice president and general sales manager of Elliott Co., until his retirement in July of this year, died August 25.

Frank J. Wood, formerly with Lombard Corp. from which he retired January, 1960, died July 12, 1961. Mr. Wood was a life member of AISE, joining the Association in 1926.

Alfred R. Abelt, 71, former vice president of sales and director of Chain Belt Co., died September 11.

H. Stanley Rogers, chairman of the board, American Shear Knife Co., died September 8. Mr. Rogers was a co-founder of the company in 1933.

A. J. Boynton, president of A. J. Boynton Co., died August 18. After early experience in the steel industry, Mr. Boynton spent a number of years with H. A. Brassert Co. before forming his own organization.



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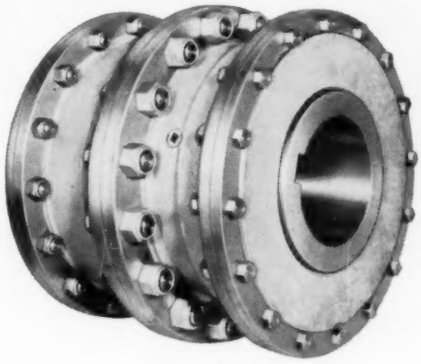

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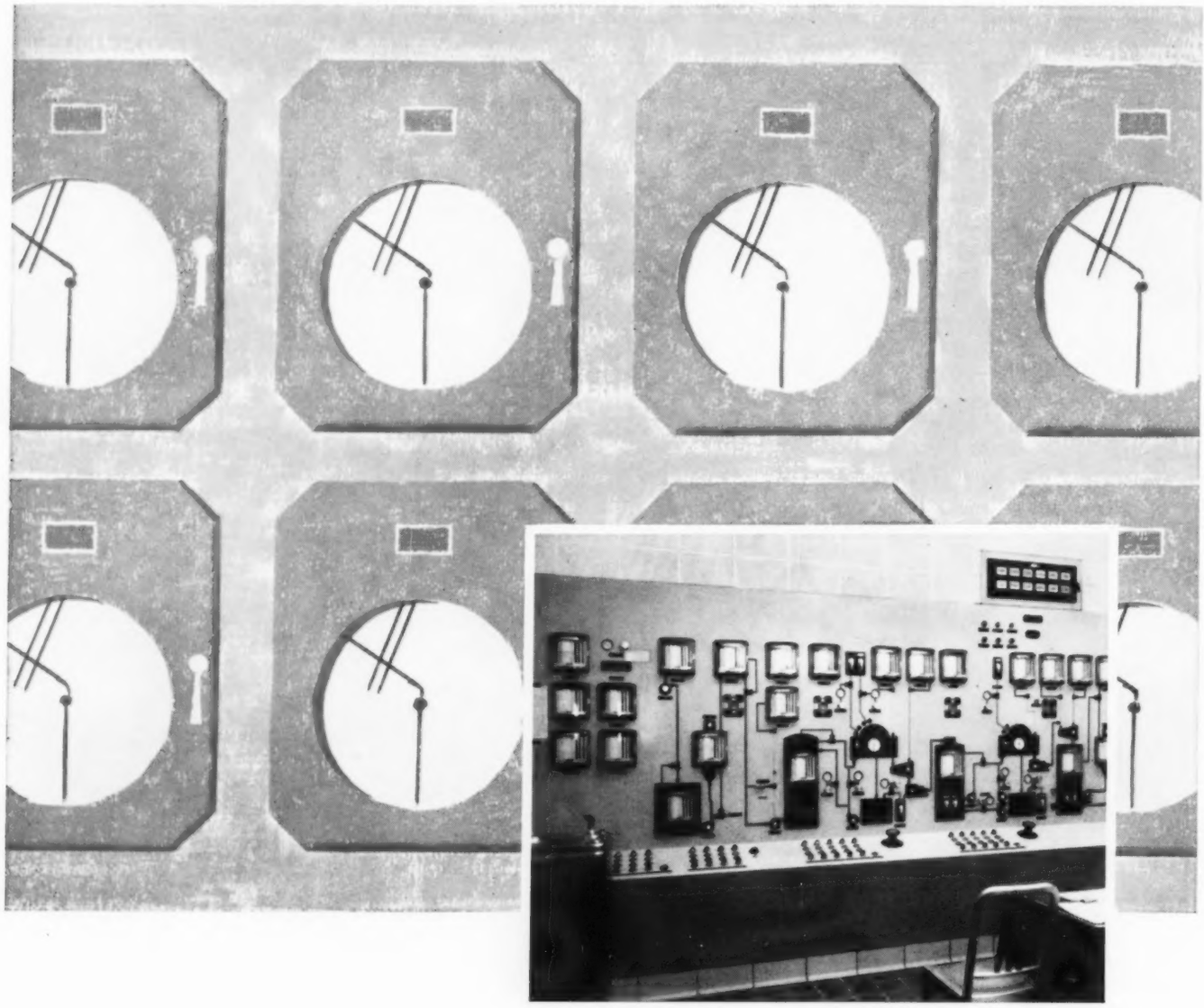

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New Taylor "MAG-PIPE"* Magnetic Flowmeter Transmitter permits use of miniature instruments to $ave Panel $pace . . . and, for the first time, gives High-Accuracy Transmission over great distances . . .

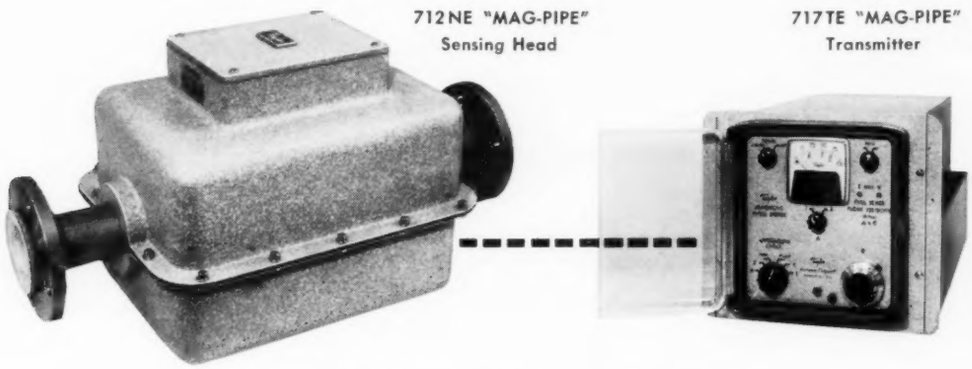
Not only does this outstanding new Taylor flow transmitter give you a very high degree of accuracy, it also permits conservation of panel space by use of miniature instruments, and transmission over greater distances. Designed to measure flow of fluids with an electrical conductivity as low as that of distilled water, it is ideally suited for very low flows, viscous liquids and liquids containing suspended solids. The flow is in no way restricted by the primary element.

The "MAG-PIPE" sensing head is mounted in the flow line. It comprises a flow pipe, an AC magnetic circuit and two electrodes. Sensing head housing is "hose-down proof" (explosion-proofing optional), and has lapped joint (Van Stone type) flanges for easier installation.

The transmitter employs solid state components, being fully transistorized for long-term reliability. It is standard in fixed-range form, in which case calibration is factory set at the desired range. Optionally available with a full-scale vernier adjustment and a 2-position range switch to measure any range between 1 and 30 ft./sec. A built-in output meter doubles as circuit checking device.

• • •

The "MAG-PIPE" Flowmeter Transmitter is in production. Consult with us on your difficult flow measurement problems. See your Taylor Field Engineer or write for **Bulletin 98418.** Taylor Instrument Companies, Rochester, N.Y., and Toronto, Ontario.



712NE "MAG-PIPE" Sensing Head

717TE "MAG-PIPE" Transmitter

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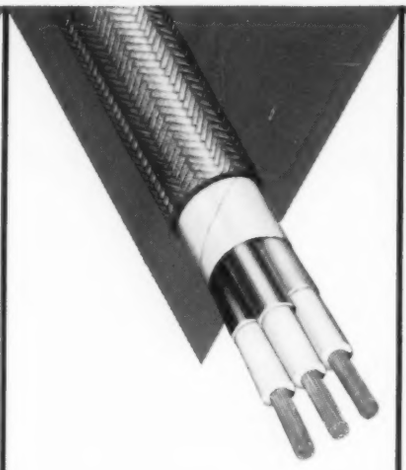
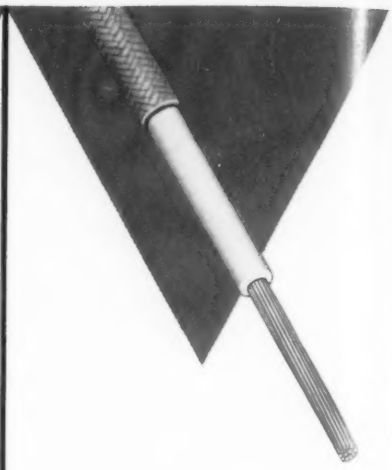
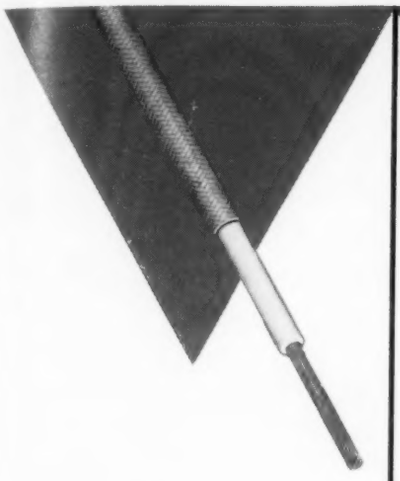
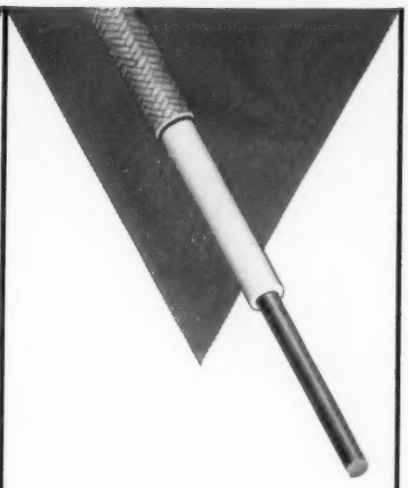
	POWER CABLE	 CONTROL CABLE	 APPLIANCE and FIXTURE WIRE
Voltage	600 and 5000 volt	600 volt	300 and 600 volt
Operating Temperature	125°C	125°C	150° and 200°C
Size Range	600V: #14 AWG to 500,000 CM 5000V: #8 AWG to 500,000 CM	#14 — #9 AWG	150°C: #22 to #18 AWG — 300 volt #22 to #10 AWG — 600 volt 200°C: #18 to #12 AWG — 600 volt
Construction	**Conductor** — Tinned copper, stranded **Insulation** — Silicone rubber **Covering** — Asbestos braid	**Conductor** — Tinned copper, stranded **Insulation** — 3/64ths silicone rubber, glass braid, color coded **Covering** — Cable tape, asbestos braid. Also available in galvanized steel, aluminum or bronze interlocked armor	**Conductor** — Tinned or nickel plated, stranded or solid **Insulation** — Silicone rubber **Covering** — Glass braid
Applications	Power wiring in high ambient temperature locations. Allows the most efficient utilization of the conductor. Satisfactory for installations in wet or dry locations.	Recommended where control or signal circuits are exposed to high ambient operating temperatures... steel mills, power stations, automotive, cement and glass plants.	For wiring of high wattage units, such as lighting fixtures, clothes dryers, sun lamps, stoves, electronic equipment, water heaters, ovens, and other apparatus.

Wire & Cable Selector





APPARATUS and MOTOR LEAD WIRE	LIGHTING WIRE
600 volt	600 volt
200 C	125°C
#20 to 4/0 AWG	#14 to #8 AWG
Conductor — Tinned copper, stranded **Insulation** — Silicone rubber **Covering** — Glass braid	**Conductor** — Solid tinned copper **Insulation** — Silicone rubber **Covering** — Glass braid
For leads to motors and transformers in high temperature locations. Stands up excellently under varnish dip and bake processes.	For lighting circuits in high ambient temperature locations.

Rockbestos Silicone rubber cables give you these outstanding advantages:

- excellent heat resistance 125°C-200°C allowable conductor temperature
- flame resistant—slowly forms non-conducting ash maintaining circuit integrity
- corona and ozone resistant
- maintains flexibility from —130°F to +500°F
- excellent resistance to oil, solvents, fuels and chemicals
- excellent electrical properties

ROCKBESTOS WIRE AND CABLE CO.
division of **CERRO CORPORATION**
Nicoll and Canner Sts., New Haven, Conn.

Gentlemen:

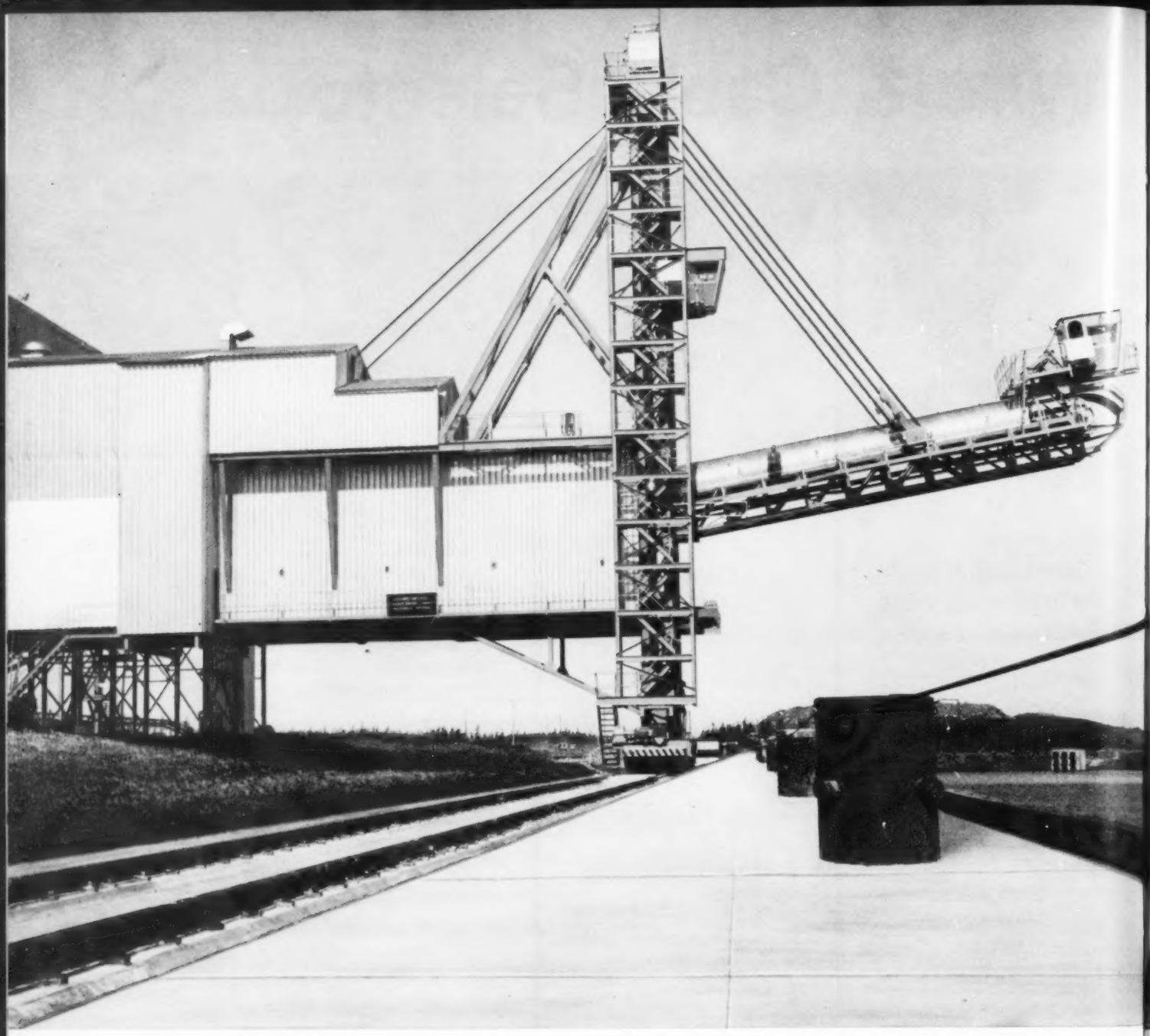
I would like to know more about the unique advantages of Rockbestos Silicone Rubber Wire and Cable. Please send me the following:

- ☐ The Rockbestos Silicone Wire & Cable Catalog.
- ☐ A sample of your silicone rubber wire.
- ☐ Please have distributor or salesman call.

Name_____

Company_____

Address_____



This shiploader handles 10

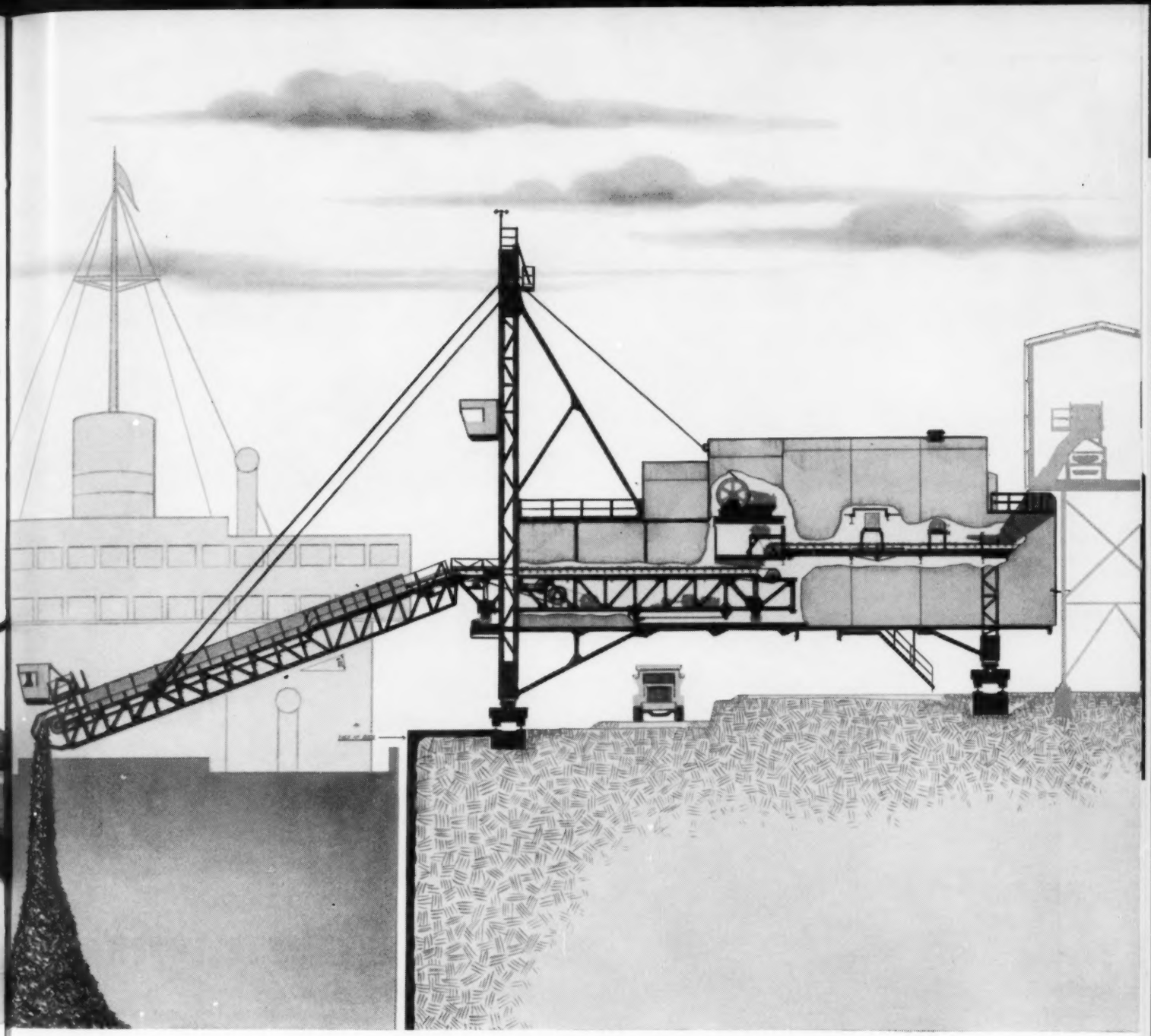
The loader is the final step in the 191-mile haul of ore from the Lac Jeannine mine site to cargo ships at Port Cartier, Quebec.

One of the largest of its kind in the world, this huge shiploader handles 6,000 tons of iron ore concentrate per hour. The detail design, fabrication and construction were carried out by Dominion Bridge for Quebec Cartier Mining Company. Consulting Engineers were C. D. Howe & Co. Ltd.

Differing from the stationary type of loader which demands movement of the vessel, this shiploader is mounted on four sets of trucks and moves along tracks at the dockside to any hatch desired.

Loading is accomplished by means of endless belt conveyors which transport the ore from the storage building to the shiploader. A travelling shuttle, with a pivotted boom, supports the shiploader conveyors and the entire unit can travel a distance of 50 feet.

The working range of the boom is from 20 degrees below to 10 degrees above the horizontal position. To clear shipping, the boom is



100 tons of ore per minute

raised to a fixed position70 degrees above the horizontal. Combination of these movements permits accurate positioning of the boom over hatches of ships with different beam widths and deck elevations. A built-in weighing feature can be preset to automatically deliver the amount of ore required for each hatch.

Dominion Bridge manufactures many types of handling equipment including overhead cranes, grain car dumpers, unloading towers, pulpwood stackers, travelling ore and coal bridges, and open hearth charging machines. The experience of our Mechanical Division is at your service. 89

Mechanical Division **DOMINION BRIDGE**

FIFTEEN PLANTS COAST-TO-COAST

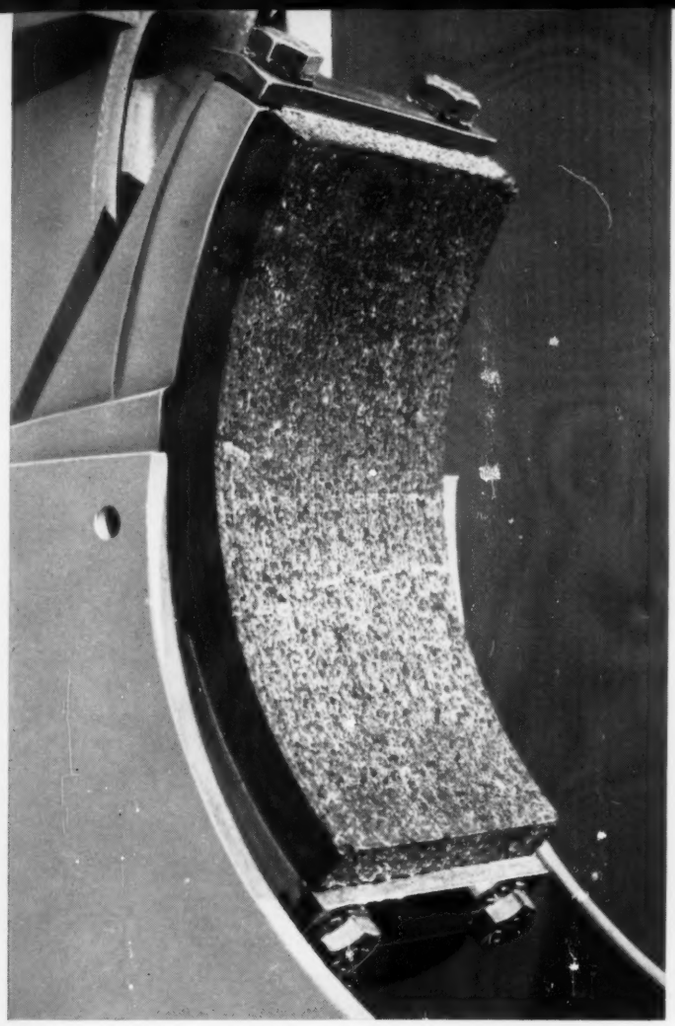
This General Electric d-c brake has been at work for seven years! In 1954, it was installed on a slab depiler at the Jones & Laughlin Steel Corp., Cleveland. Lower photo shows the brake shortly after installation. Top photo was taken just a few weeks ago. It's the same brake! J&L reports that the only maintenance ever required has been occasional adjustment to compensate for shoe wear, and replacement of normal wear parts.

GENERAL ELECTRIC'S

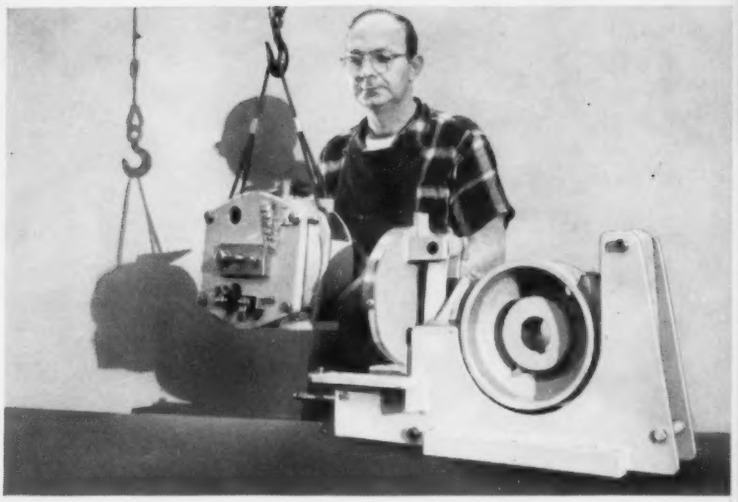
Seven

In 1954, General Electric introduced the first d-c magnet brake designed and built to NEMA-AISE standards. This two-shoe, single-magnet, single-armature brake responds rapidly to prevent load slippage or coasting after motor power is cut off.

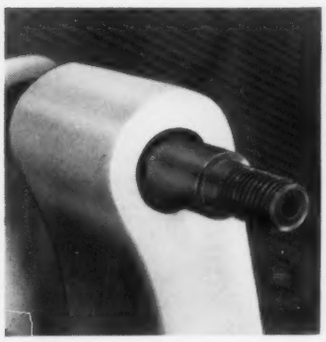
In seven years, this General Electric brake has been put to work on industry's toughest jobs—rolling mills, cranes, ore unloaders . . . all types of equipment requiring positive stopping and holding of heavy loads. Hundreds



1961 Just announced: Bonded linings now replace riveted linings—exclusively on G-E d-c brakes. Result is 50% longer life due to greater braking surface, thicker usable lining. Rivet-scored wheels are a thing of the past. And bonding is five times stronger than riveting formerly used!



1960 Complete magnet housing replacement is accomplished in minutes. Both magnet and coil remove vertically or horizontally without disturbing linkage or settings.



1956 Self-lubricating sintered-brass bearings eliminate need for periodic greasing. Now, in 1961, they're sealed to keep out damaging dirt.

1954 Slip-out brake linings remove easily with screwdriver after removal of only two holding bolts. No torque readjusting needed.

AMAZING DC MAGNET BRAKE

years of sure stops

of users attest to its positive performance, outstanding reliability, unusually low maintenance.

CONTINUED DESIGN IMPROVEMENT

Yet, General Electric engineers have never stopped development work on the d-c brake. Year by year, new, thoroughly tested features have been added . . . many readily adaptable to brakes already in service. Several features of today's G-E brake are pictured. Here are other important user benefits:

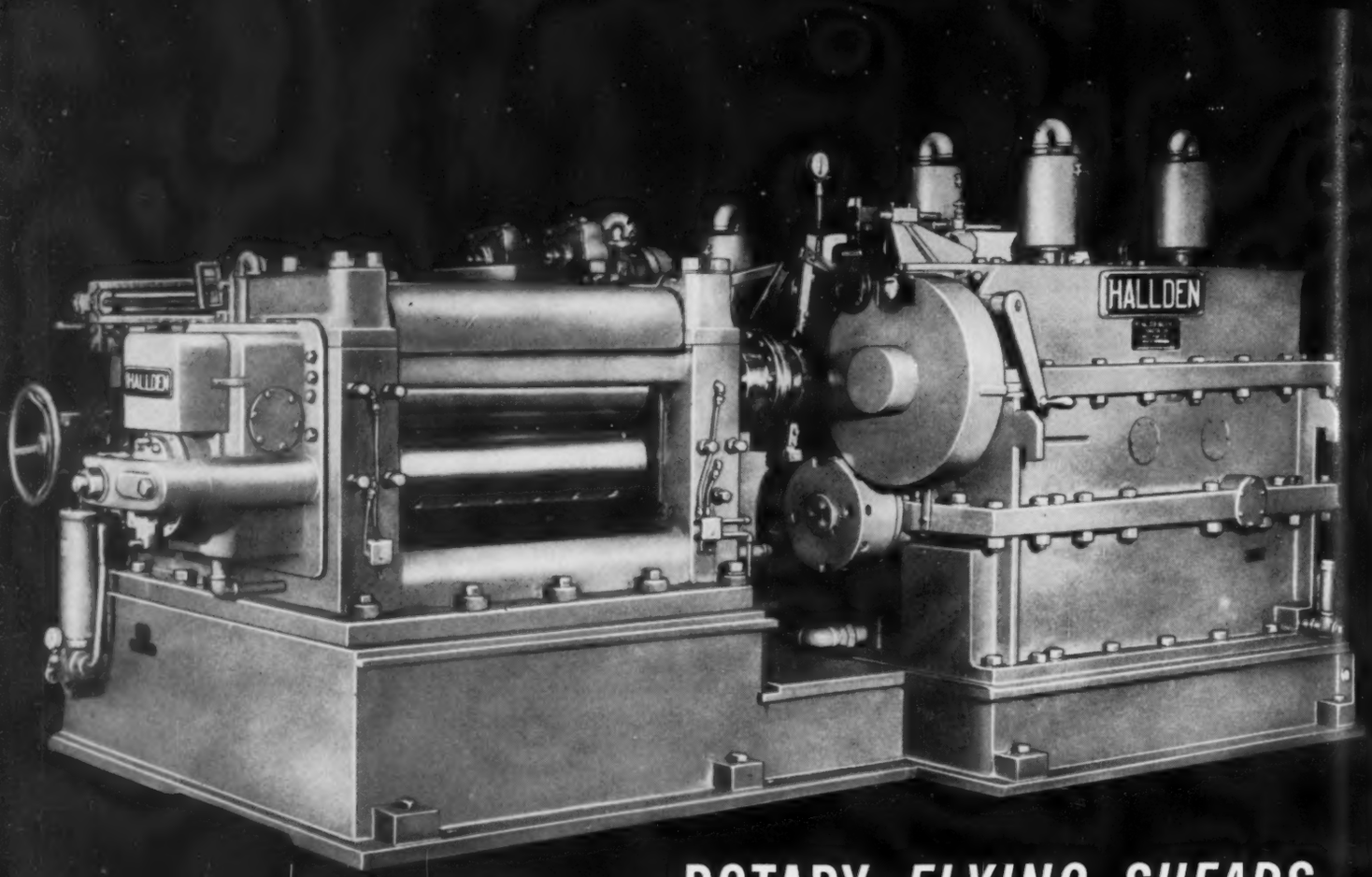
- Dust and grit simply fall through the new cutaway armature—greatly reducing downtime for cleaning.
- Damaging dust can't get through new rubber "O" rings around bushings.
- Higher temperature ratings, greater mechanical and dielectric strength are inherent in the epoxy-encased coil.
- Both the wheel and the brake linings are removable without energizing the brake or re-adjusting torque, by engaging the manual-release mechanism.
- Indication of lining wear takes only a glance at the armature-gap indicator.
- Shoe clearance and armature gap can be set from adjustments on one end.

If you have a job for a d-c brake or are planning one, let your G-E Sales Engineer show you why General Electric's amazing d-c magnet brake is by far your best buy. Or, write to Section 784-29, General Electric Co., Schenectady 5, N. Y.

Industry Control Dept., Salem, Va.

Progress Is Our Most Important Product

GENERAL ELECTRIC



ROTARY *FLYING SHEARS*
with "PUSH BUTTON" CONTROL
for HIGH PRODUCTION.... up to 8 cuts per second
ULTIMATE ACCURACY.....

- **SYNCHRONIZED**
- **MICROMETER ADJUSTMENT for both cut lengths and synchronization**
- **ADJUSTMENTS "ON THE FLY" if desired**
- **TORQUE CORRECTIVE GEARING**
- **DYNAMICALLY BALANCED**

HALLDEN

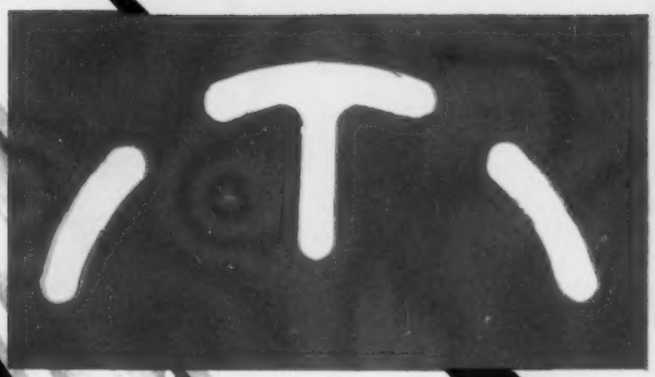
The world's leading machinery manufacturers rely on Hallden shears in their process lines

THE HALLDEN MACHINE COMPANY • THOMASTON, CONNECTICUT

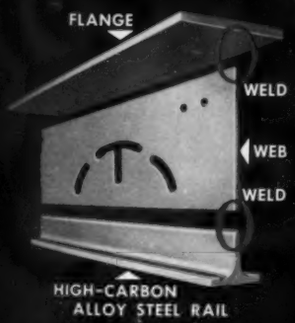
Associates: The W. H. A. Robertson & Co., Ltd., Bedford, England

A NEW
HEAVY-DUTY OVERHEAD TRACK BY CLEVELAND TRAMRAIL

TARCA TRACK



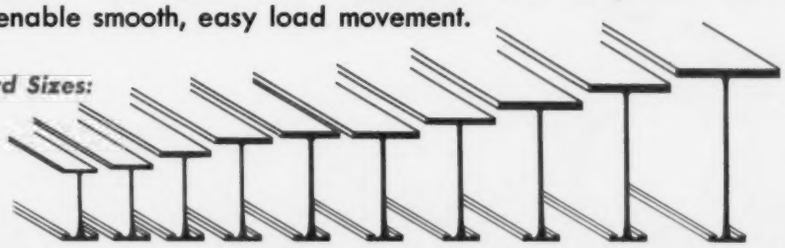
- **Completely new - - in design - - in fabrication**
- **Assures more years of heavy-duty service**
- **Great rigidity**
- **Maximum strength with minimum weight**
- **Design readily proportioned to suit any load condition**
- **Overcomes track peening**
- **Greater range of sizes**
- **New support fittings expedite erection**



Cleveland Tramrail Tarca Tracks are a tremendous innovation in the overhead materials handling field. Another great improvement among many by Cleveland Tramrail to keep it far in the lead.

Tarca Tracks are straight, true, accurate—have flat raised treads—of hard, high-carbon alloy steel—prevent peening—provide greater wear resistance—enable smooth, easy load movement.

10 Standard Sizes:



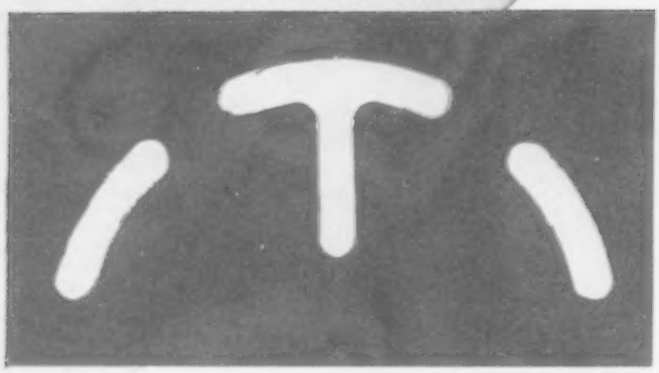
Sizes range from 8″ to 20″. Also special sizes are easily made to suit any overhead crane or monorail requirement. Tarca Track matches with existing Cleveland Tramrail track installations.

Tarca Tracks are made under carefully controlled conditions. The three parts, top flange, web and alloy steel rail, are joined by continuous welds to form an integral one-piece section.

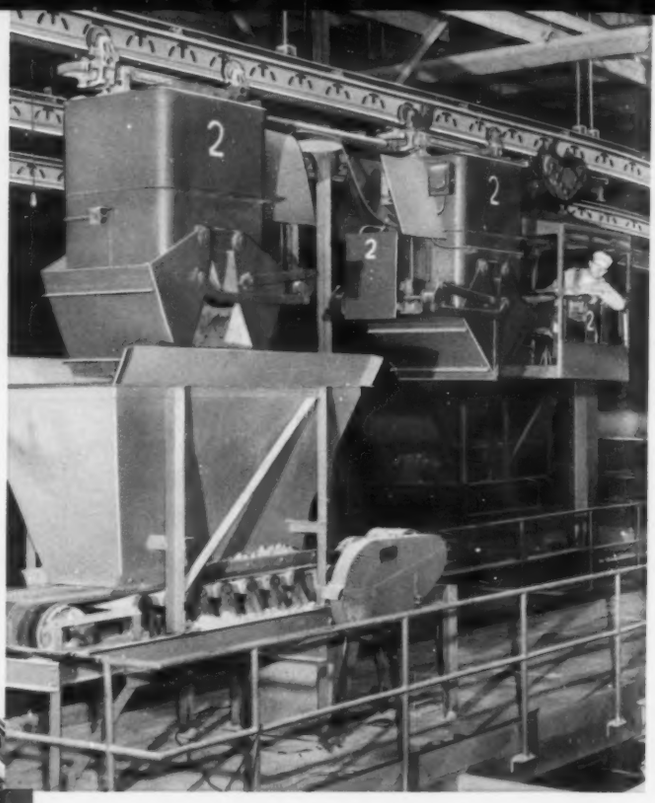
Ask for this helpful booklet—No. 2032

Covers all major features the buyer should know about overhead materials handling equipment. Has complete story on Tarca Track. Contains detailed equipment specifications and handy proposal evaluation form.

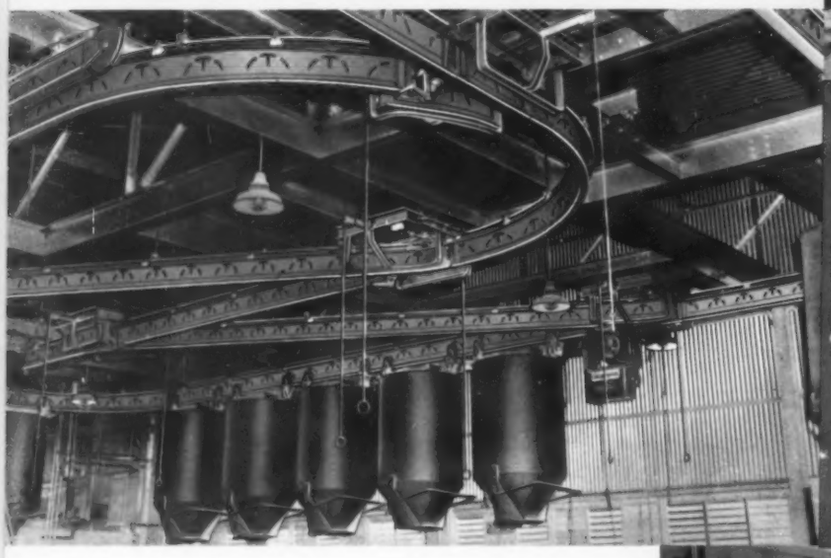
CLEVELAND TRAMRAIL DIVISION
THE CLEVELAND CRANE & ENGINEERING CO.
5899 EAST 284th STREET · WICKLIFFE, OHIO



Trade—mark of durability and strength —punched into all Tarca Tracks.

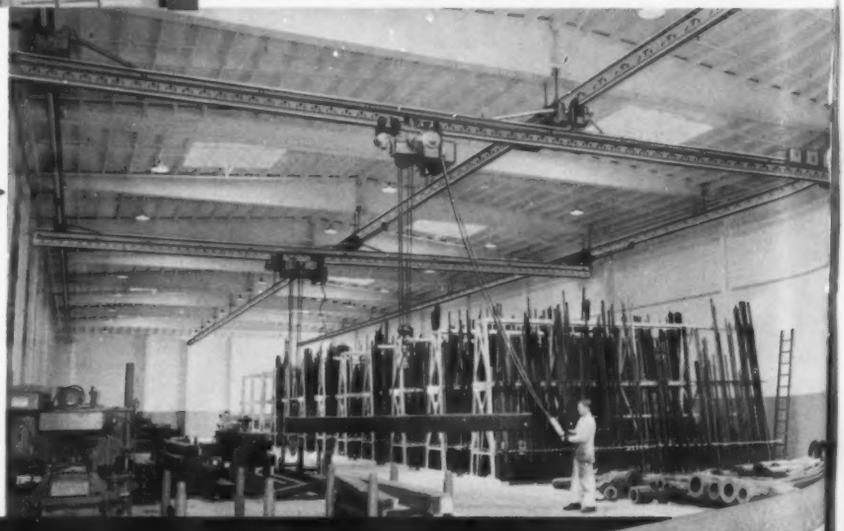


Cleveland Tramrail has an enviable reputation throughout the Ceramic Industry for outstanding performance. Customers have reported that their installations subject to heavy, continual usage are serving them far beyond expectations.



In the Glass Industry Cleveland Tramrail advanced a method of handling mixed ingredients in buckets traveling between mixer and furnaces which prevents segregation. This has proven so successful in assuring uniform quality that today the entire production of many glass plants is dependent upon equipment like that illustrated here.

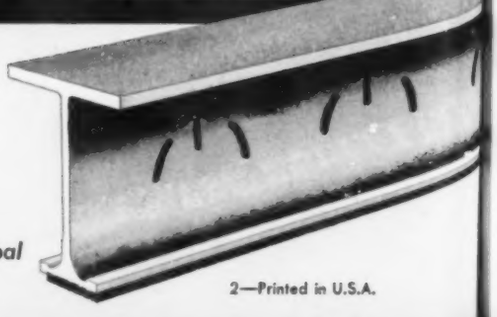
Cleveland Tramrail floor-operated cranes are such an important factor in handling heavy materials and cutting costs that there are now thousands of installations serving factories, mills and warehouses. Tarca Track is of real advantage for crane systems because of its great resistance to deflection.



Your Cleveland Tramrail Sales Engineer is Qualified to give you the Complete Design and Application Story on This Revolutionary

NEW TARCA TRACK

Cleveland Tramrail is represented by competent, experienced engineers in all principal cities of the United States and Canada. Contact address on other side.



2—Printed in U.S.A.

"NOT MUCH FOR PRETTY, BUT HELL FOR STOUT"

This Whiting Ladle Pouring Car was designed with one thought in mind . . . to fill more ingot molds, faster and at lower cost, than any other method. Extra-rigid construction ignores weight and heat of melt. Fail-proof hydraulic mechanism moves car at any speed from 0 to 100 fpm, positions ladle smoothly, precisely to left or right above mold. Viewed from the vantage of profits earned, this homely brute-for-punishment is downright beautiful.

Whiting engineers specialize in cost-cutting equipment for foundries . . . Whiting cupolas and mechanical charging systems, Hydro-Arc electric furnaces, cradle type air furnaces, pulverizers, more than 200 ladle types and models. They offer an unusual wealth of practical experience to help you lower costs while improving quality. No charge for detailed consultation nor accurate cost estimates. No obligation, either.

FREE: Bulletin FY 179, *Mechanical Charging Systems*, helps you select the most profitable system for your particular operation. Write for your copy to: *Whiting Corporation, 15655 Lathrop Avenue, Harvey, Illinois. In Canada: Whiting Corporation (Canada) Ltd., 350 Alexander Street, Welland, Ontario, Canada.*

90 OF AMERICA'S "FIRST HUNDRED" CORPORATIONS ARE WHITING CUSTOMERS

WHITING

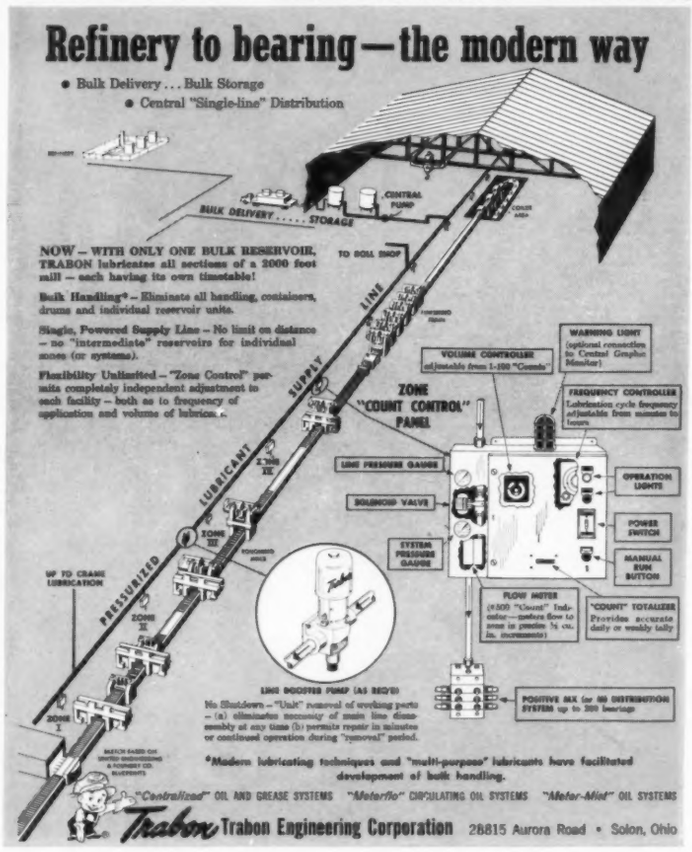
METALLURGICAL EQUIPMENT DIVISION

MANUFACTURERS OF CRANES: TRAMBEAM® HANDLING SYSTEMS; PRESSUREGRIP;® TRACKMOBILES;® FOUNDRY, RAILROAD, AND SWENSON CHEMICAL EQUIPMENT

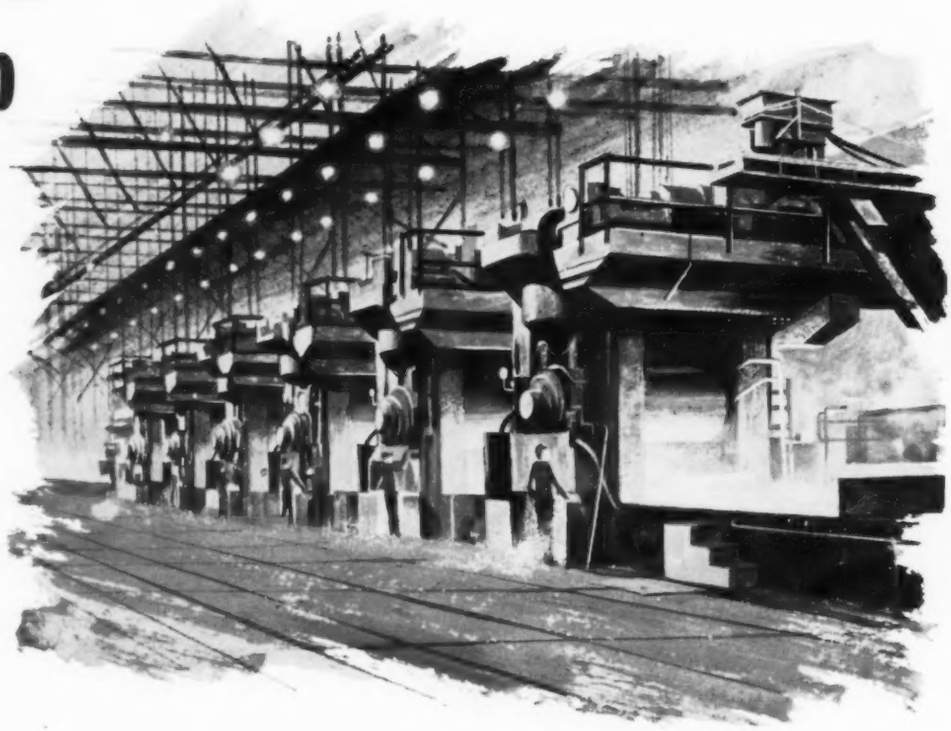
TRABON®
CENTRALIZED LUBRICATING SYSTEMS

It's bulk handling from refinery to bearing

Great Lakes Steel's newest facility is the most automated mill in the world. What centralized lubrication system did Great Lakes Steel choose to protect the huge bearing investment in this mill? Trabon, of course! What's more, it's **the new Trabon bulk handling system** where the grease is treated as a utility, providing you with increased efficiency and flexibility — you can add systems or service outlets with no additional pump cost. You gain better housekeeping and promote safety. Your maintenance and operating costs are lower and . . . you have **better** lubrication. Trabon provides you with the cost saving advantages of automated bulk handling. Write us for technical data on bulk handling as well as other versatile Trabon systems.


Refinery to bearing—the modern way
• Bulk Delivery . . . Bulk Storage
• Central "Single-line" Distribution
BULK DELIVERY
STORAGE
CENTRAL PUMP
NOW – WITH ONLY ONE BULK RESERVOIR, TRABON lubricates all sections of a 2000 foot mill – each having its own timetable!
Bulk Handling* – Eliminate all handling, containers, drums and individual reservoir units.
Single, Powered Supply Line – No limit on distance – no "intermediate" reservoirs for individual zones (or systems).
Flexibility Unlimited – "Zone Control" permits completely independent adjustment to each facility – both as to frequency of application and volume of lubricant.
TO ROLL SHOP
SUPPLY LINE
LUBRICANT
PRESSURIZED
UP TO CRANE LUBRICATION
ZONE "COUNT CONTROL" PANEL
VOLUME CONTROLLER
WARNING LIGHT
FREQUENCY CONTROLLER
LINE PRESSURE GAUGE
SOLENOID VALVE
SYSTEM PRESSURE GAUGE
OPERATION LIGHTS
POWER SWITCH
MANUAL RUN BUTTON
FLOW METER
"COUNT" TOTALIZER
LINE BOOSTER PUMP (AS REQ'D)
No Shutdown – "Unit" removal of working parts – (a) eliminates necessity of main line disassembly at any time (b) permits repair in minutes or continued operation during "removal" period.
POSITIVE MIX (or SD DISTRIBUTION SYSTEM up to 200 bearings
*Modern lubricating techniques and "multi-purpose" lubricants have facilitated development of bulk handling.
"Centralized" OIL AND GREASE SYSTEMS "Meterflo" CIRCULATING OIL SYSTEMS "Meter-Mist" OIL SYSTEMS
Trabon Trabon Engineering Corporation 26815 Aurora Road • Solon, Ohio

World's fastest, most automated Hot Strip Mill goes Trabon



AT GREAT LAKES STEEL in Detroit, the computer-controlled and operated 80" Mill of the Future—fastest, most powerful hot-strip mill in the world—will provide more and better automobile body sheets. Trabon delivers exact amounts of lubricant to all bearings on this mill.

PLUS + POSITIVE "Centralized" OIL AND GREASE SYSTEMS "Meterflo" CIRCULATING OIL SYSTEMS "Meter-Mist" OIL SYSTEMS

Trabon® Trabon Engineering Corporation 28785 Aurora Road • Cleveland 39, Ohio

Equipment News...

LIMIT SWITCH

△ A rotating-cam limit switch with 1 to 12 cam-operated switches is announced by The Clark Controller Co. The Bulletin 102 Type CL features sealed, lifetime lubricated ball bearings and double-break silver-to-silver contacts. The shaft of this control device may be connected to a rotating element by direct coupling, or driven by a gear-train or roller chain. Each adjustable cam operates a separate switch which can limit the travel of a machine member or initiate operating function for any length of angular travel from 18 to 360 deg.

Maximum recommended speed of the shaft on the limit switch is 75 rpm. For drive speeds in excess of this, gear reducers with many different ratios from 4/1 to 800/1 are available. In addition, reducers with special ratios can usually be made to order. Below a shaft speed of approximately 15 rpm, snap-action contacts can be supplied and are recommended for many applications for accurate, trouble-free service. These contacts have ac ratings 15 amp at 115 v, 10 amp at 220 v, 6 amp at 440 v and dc ratings of 2.0 amp at 115 v, 0.5 amp at 230 v and 0.1 amp at 600 v.

CONVEYOR BELTING

△ Announced by the May-Fran Manufacturing Co., a division of Fischer & Associates, Inc., is a new line of patented, flat-top, hinged-steel conveyor belting and flat-top belt conveyors. The newly-patented link design permits construction of a flat, continuous load-supporting conveyor surface for above floor or flush-with-floor installations.

The patented, end-curved, interlocking and overlapping steel belt links are precision formed to provide an almost smooth-top carrying surface. Through shafts, at each pitch, extend to join the side drive chains and position them. (Pitch is the distance between centerlines of link through holes.) Intermediate connectors are used to fit over the through shafts. These are attached to the underside of the belt, tying the entire assembly into an integral rigid unit that is easy to assemble and disassemble.

Conveyors can be designed to transport loads in one, or in two directions. One-way flat top belting is nonreversible. Two-way flat-top belting is designed for reversible conveyor systems and will transport the load in either direction.

The belting can negotiate convex or concave curves with safety. The hinged-steel interlocking belt design maintains closely fitted joints at all times, eliminating the operating safety hazards found with slat-type flat-top conveyors. Close belt clearances prevent tools and assembly items from falling through.

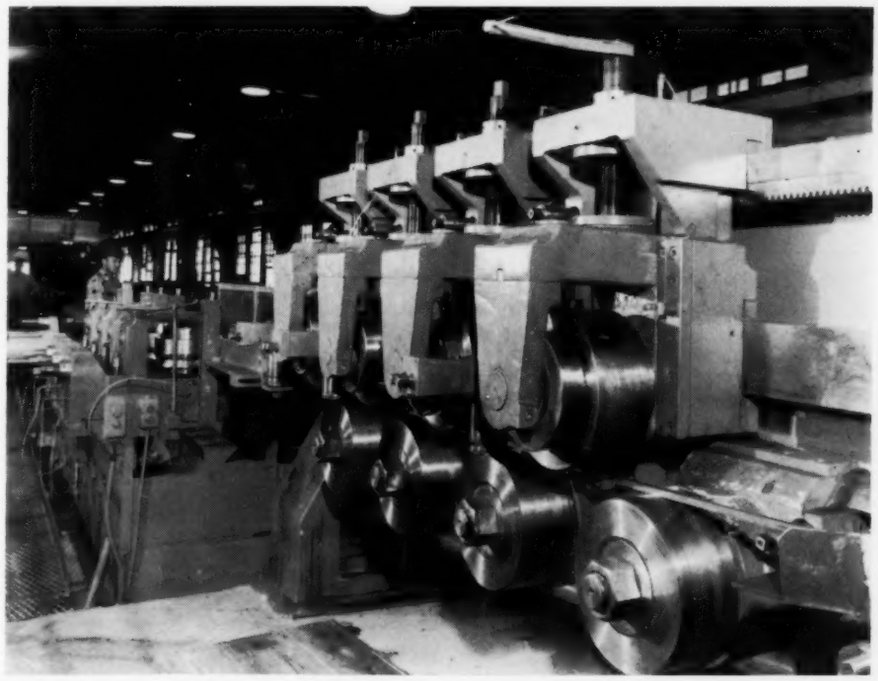
The new flat-top hinged-steel belting permits installation of above floor, or flush-with-floor conveyors. This design forms "a moving sidewalk," that can efficiently handle bulky, hot or heavy materials and assemblies. There are no stationary or moving parts that extend above the belt. This permits handling of materials and assemblies that are wider than the conveyor. Pallets of parts and packages can easily be picked up from the moving belt and unloaded where needed.

Even while in motion, the flat-top conveyor permits a cross flow of foot or vehicle traffic without interrupting normal plant traffic flow.

Flat-top hinged-steel belt conveyors can be designed and supplied

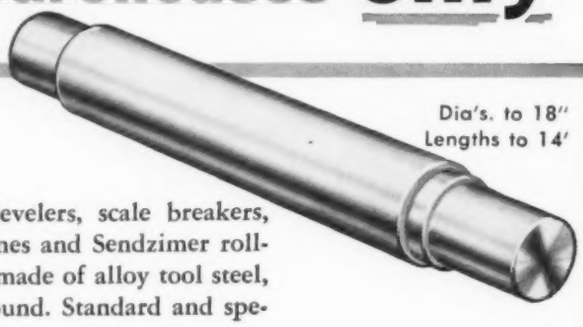
STRAIGHTENING UNIT HANDLES COLD DRAWN SHAPES

This #4 size Blaw-Knox Medart TPOMVC-type shape straightening machine at Wisconsin Steel Division of International Harvester Co., handles all of the types of cold drawn shapes, including squares, flats and hexagons. Design of the machine features a variable bending span on the rolls which permits spreading the roll centers farther apart or closer together, resulting in greater straightening accuracy on a wider range of products. This unit is designed to handle squares up to three in., flats up to 1 x 6 in. and hexagon bars up to three in. It is a high production unit, running at throughput speeds up to 300 fpm travel of the workpiece. Quick changeover of the rolls is possible by the modified overhung roll design.



For STEEL MILLS

and warehouses *only*



"HILL ACME" ROLLS

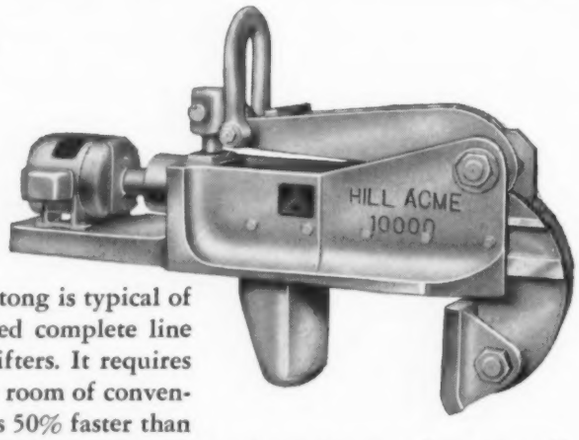
Dia's. to 18"
Lengths to 14'

Custom made for levelers, scale breakers, straightening machines and Sendzimer rolling mills. Precision made of alloy tool steel, heat treated and ground. Standard and special types.

"CLEVELAND" METAL CUTTING KNIVES

The product of forty years of experience in manufacturing alloy grade, metal cutting knives of all types for shearing hot and cold metals.

"HILL ACME" MOTORIZED LIFTERS



This vertical coil tong is typical of the newly designed complete line of HILL ACME lifters. It requires only 1/3 the head room of conventional tongs and is 50% faster than mechanical types. Gives a constant grip ratio regardless of wall thickness and can be prepositioned to eliminate damage to the coil. Available up to 80,000 lbs. capacity. Contact us for "C" hooks, Rack Lifters, Billet, Sheet, Plate, Bar, Ingot and Ingot Mould Lifters.

THE HILL ACME COMPANY

1201 West 65th Street • Cleveland 2, Ohio

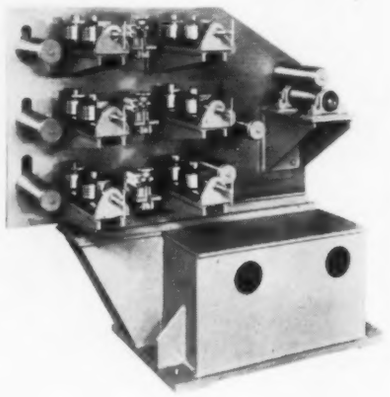
MANUFACTURERS OF: "HILL" Grinding and Polishing Machines • "ACME" Forging Machines • "CANTON" Rotary and Alligator Shears • BAR-BILLET Shears MATERIAL HANDLING Equipment • "CLEVELAND" Knives and Shear Blades.

to virtually any practical width from 12 to 60 in. Belts are available with 6 or 9-in. pitch links.

EDGE-CONDITIONING UNIT

△ The Steel Equipment Co. has built a narrow strip edge-conditioning unit for producing burr free edges on steel strapping and similar narrow strip products.

Edge conditioning is accomplished in 2 steps: burrs are shaved from the strip as it passes through special



burr shaving rolls. The second set of vertical edging rolls rounds the corners of the stock to provide a smooth edge with no sharp corners. The edge conditioner is of the "pull-through" type (not driven).

This unit can be furnished as a separate line for single or multiple strands, complete with necessary uncoiler and recoiling equipment. Also this edge-conditioning unit can be furnished as part of a slitting line.

A sturdy welded steel base supports each of the major components in this high production unit.

BONDED BRAKE LINING

△ General Electric Co. is marketing a new line of rivetless bonded industrial brake linings according to the Industry Control Department.

Field trials of the bonded linings have proved them feasible and satisfactory for heavy duty steel mill and industrial applications, the department said.

Bonded linings offer several important advantages to users, the trials showed, including:

Longer lining life because of effectively thicker lining;

No rivets to score brake drums as lining wears;

TIPS FROM A ROLL MAKER'S NOTEBOOK

MACKINTOSH-HEMPHILL DIVISION, E. W. BLISS COMPANY, Pittsburgh 3, Pennsylvania

Cast mill rolls • Cinder pots • rotary tube straighteners • end-thrust bearings • heavy-duty lathes • steel and special alloy castings

Plain body rolls are a good buy for merchant mills

Ordering your roughing and intermediate stand rolls with plain bodies can save you money two ways – initially in the price of the roll, as a result of lower turning and molding charges and secondly, by reducing your roll inventory. When you cut your own passes, you have complete latitude in your use of the rolls, since you can "tailor" the rolls for your specific demands.

HARDNESS PENETRATION THE SECRET

Naturally, buying plain merchant mill rolls involves some care in choosing a suitable analysis: the rolls you order must have sufficient hardness penetration to provide for any of the pass depths you will need.

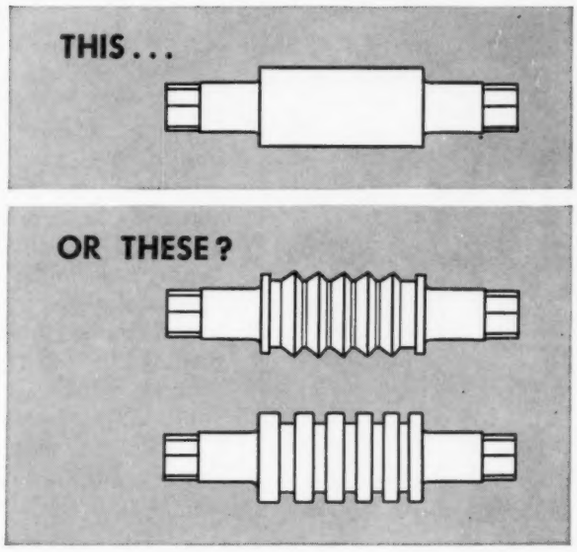
This is not as much a problem as it once was. Recent developments in roll metallurgy and heat treatment have made it possible to produce constant hardness from the surface to the center of the alloy steel rolls that we normally recommend for merchant mill service.

Thus, the only considerations are the severity of the service, and the hardness level that will provide the wear resistance the rolls need to serve any given campaign without requiring redressing.

The Mack-Hemp rolls that have proved themselves time and again in merchant mills are –

Technikrome—Formerly adamite, this is one of the most popular of all trade-named alloy steel rolls on the market. It is available in a wide range of carbon contents and heat treatments, with hardness from 36 to 52 Shore (C Scale).

Supermetal – Higher in alloy content, this roll possesses qualities common to cast steel in its strength and to cast iron in its wear resistance. Its fine, homogeneous structure makes it suitable for finishing rolls as well as roughing and intermediate stands. Available in hardnesses up to 55 Shore.



Stironite – An alloy steel in which the graphite occurs in unusually small particles, distributed uniformly throughout, thus possessing the finishing qualities of cast iron. These rolls are especially well suited for finishing. Available in hardnesses from 42 to 55.

All these roll analyses are stronger than the latest types of alloy cast iron, and, in the case of Supermetal and Stironite, as pointed out above, have many of cast iron's advantages as a material for mill rolls.

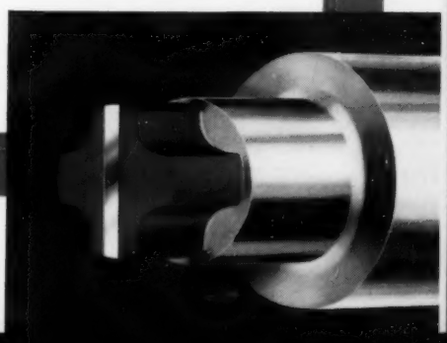
Whatever the type of mill you operate, you'll find that our trained roll engineers, backed by Mack-Hemp's 138 years of experience with mill rolls, can give you helpful advice on any rolling problem that's bothering you. Their assistance is yours for the asking. Simply write or telephone us at HEmlock 1-3000.

MACKINTOSH-HEMPHILL

You get more tonnage from "the rolls with the Striped Red Wabblers"

Division of E. W. BLISS COMPANY

Presses, Rolling Mills, Special Machinery



Taylor's Tougher end to end!

SIZES—9/32" thru 2"

Special analysis alloy steel . . . electric flash welding . . . controlled heat treating and patented Tayco Hooks make TM Alloy Sling Chains tougher! Link-by-link inspection, scientific testing and signed Test Certificate are additional reasons why TM Alloy Chain is preferred by safety engineers . . . material handling men . . . production superintendents! Call your distributor or write for Bulletin 14-A.

Chain is our specialty—not our sideline!

Taylor Made CHAIN SINCE 1873

S. G. TAYLOR CHAIN CO., Inc.
General Office: Hammond, Indiana
Plants: Hammond, Ind., and Pittsburgh, Pa.

Brake lining assemblies five times stronger than riveted types;
Ten percent greater braking surface by eliminating rivet holes; and
Elimination of maintenance operations required in riveting replacement linings.

Bonded linings are now standard equipment on General Electric's type IC9528 brakes.

New type bonded linings are interchangeable with riveted linings on all IC9528 brakes, the department added.

As before, replacement of the new bonded linings in General Electric's IC9528 d-c brake will require no disassembly of the brake or demounting of brake shoes. Removal of two bolts unclamps each lining backplate from its shoe, after which it may be slipped out around the brake wheel and a new lining slid into place along a grooved track in the brake shoe.

The new linings are bonded to steel backplates by a superior compound applied under pressure. According to laboratory tests performed by the department, this bond will withstand shearing forces greater than that required to destroy the lining—it is stronger than the lining material itself.

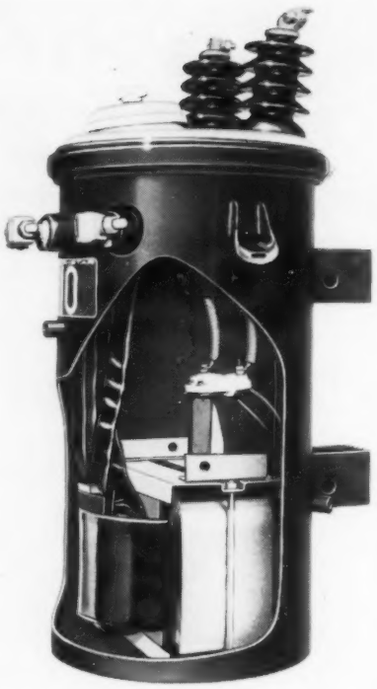
Greatly increased mechanical strength of the lining assembly results from the uniform bonding of the lining to the backplate over its entire surface. This minimizes points of mechanical stress and makes each lining as much as five times stronger than riveted types.

Additional savings to users will result from the elimination of the customary disassembly, drilling and riveting operations formerly required to replace brake shoes.

TRANSFORMER

△ Developed by H. K. Porter Co., Inc., Delta-Star Electric Division, the new DS-50 Bonus Line of distribution transformers mark the first use of aluminum strip in the low voltage winding. A new core design eliminates mechanical stress in the final form, providing maximum magnetic performance.

The low voltage windings of the DS-50 are made with aluminum strip conductor the full width of the coil. Optimum magnetic balance between the two windings is obtained, enabling the new units to withstand



short circuit currents of more than 50 times rated current. This also means reduced weight, reduced hot spots, better regulation and longer insulation life.

The new core employs a new and unique method of fabrication that develops a stress-free assembly in rectangular configuration. Previously, comparable magnetic performance could be obtained only in a toroid shape which is unsuitable for use in distribution transformers.

Both the new aluminum strip coil winding and the new core have been engineered for maximum automated production.

SHEAR TABLE

△ An advanced back shear table for the production of small to medium-sized structural bars is announced by the Industrial Products Division of Western Gear Corp.

Already operational, the shear table cuts 60-ft lengths to an accuracy of ⅛ in. by means of a special vernier adjustment.

Individual Western Gear BSM-102 shaft-mounted gear motors mounted on the 27 conveyor rolls provide simple, easily-maintained drives.

Three massive shear gages, furnished with shock-absorbing air cylinders to minimize the hammer effect of bars hitting the gage plates, are designed with 16-in. clearance with stop plates in raised position,

preventing warped bars from hitting gage carriers.

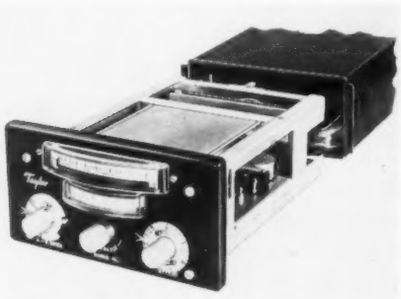
Quick-acting, disappearing side guards allow the conveyor itself to be used as a transfer table, if desired. Side guards interlock with the transfer arms, retracting when the arms are actuated. This permits use of the guards when cutting bars to length and tends to prevent warped products from drifting off the table.

The kick-off arms, line-shaft driven via a Western Gear Speed-Master parallel shaft herringbone speed reducer, are spring-loaded and impossible to jam. They, too, have a unique disappearing action on the return stroke.

CONTROL STATIONS

△ Electronic Indicating Control Stations for 24 volt and 1 volt systems are being announced by Taylor Instrument Co. as an expansion to their existing electronic line. The new 701K series of control stations feature large, full scale process indication, a complete manual power supply and a compact design for panel mounting. In addition, the chassis may be partially removed from its case while still on control, thus permitting inspection or maintenance.

A large three in. process meter and a two in. output meter are centered



on the front panel for easy viewing. Calibration of both meters is based on 1-5 ma d-c. A multi-position switch permits either automatic or manual control modes, as well as providing for balancing of the controller's operational amplifier. The fourth position of the switch allows adjustments to be made which will give a bumpless transfer from automatic to manual control.

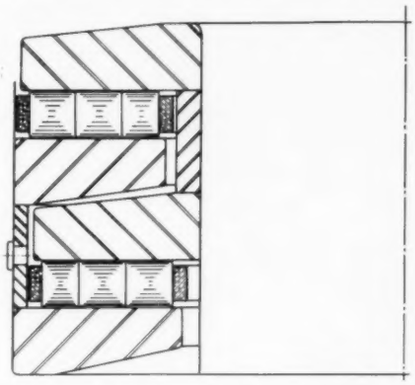
Also announced is the nonindicating version known as the 701N series. This model does not have the process indication meter but is the same in other respects.

Optional features available include a one per cent process indication meter (two per cent is standard) control point detection (for switching from manual to automatic control with no change in output) provision for cascade service and a manual loading station only.

BEARINGS

△ Designed to carry large thrust loads in applications where space is limited by bore and OD restrictions, Rollway Bearing Co., Inc., multiple-stage bearings lengthen expected bearing life by spreading the load over an increased number of bearing components.

The two-stage bearing illustrated is 42 in. in diameter, weighs approxi-

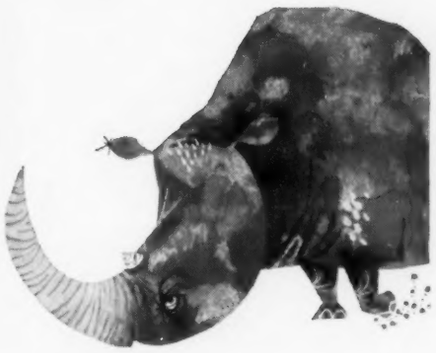


mately 5000 lb and has a dynamic capacity of 4,810,000 lb (based on 500-hr life at 33⅓ rpm). The first stage of the bearing has a capacity of 2,500,000 lb, the second stage 2,310,000 lb and a designed third stage would add an additional 1,705,000 lb of capacity. Even distribution of the load between the roller assemblies is obtained by the design of the cantilevered plates, and by the correlated thickness and length of the spacer sleeves.

In addition to providing for more load capacity in limited space, these multiple-stage bearings can provide a means for increasing capacity by adding stages. As an example, a single-stage bearing could be installed with an appropriate dimensioned filler block to allow the later addition of one or more stages to increase total capacity.

INDUCTION STIRRER

△ An induction stirring system for mixing molten steel in electric arc furnaces is now available from Westinghouse Electric Corp. Called Magnestirrer, the system works on



Tayco Hooks

Taylor's Tougher

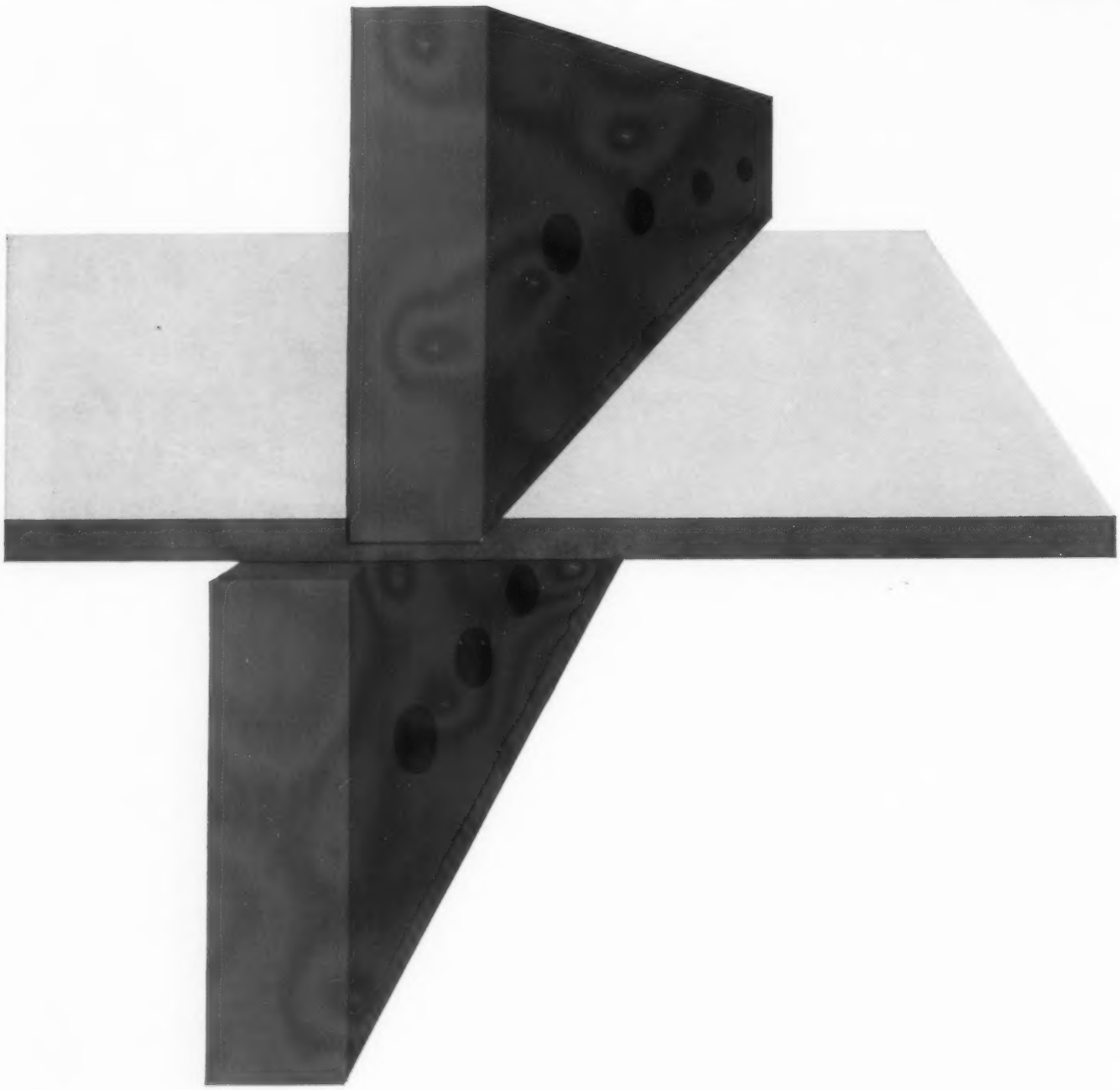
Safety Superintendents and Material Handling Engineers are getting longer, safer, more maintenance-free service from TM Alloy Sling Chains. Taylor's patented Tayco Hooks are an important reason. Channel-type construction not only protects the hooker's fingers, it also adds extra strength for tougher, safer service than conventional hooks. Get all the facts! Call your distributor or write for Bulletin 14-A.

Pat No. 2,646,306

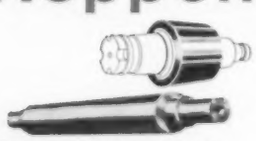
Chain is our specialty — not our sideline!

Taylor Made CHAIN SINCE 1873

S. G. TAYLOR CHAIN CO., Inc.
General Office: Hammond, Ind.
Plants: Hammond, Ind., and Pittsburgh, Pa.



Heppenstall rolls it, cuts it, handles it



Back-up roll sleeves and forged hardened, ground rolls

Side trimmer knives

Motorized sheet lifter

In the steelmaking industry — from melt shop to finished product — Heppenstall back-up roll sleeves and rolls, knives and tongs are proving their high performance value. To maintain such standards, Heppenstall has modern laboratories in each product division. All products are constantly checked — and intensive research is carried on to improve present products and to develop new ones. Heppenstall Representatives are fully experienced in the selection and application of our products to meet your problems. For service or specific information, call our nearest Representative or write us direct.

HEPPENSTALL COMPANY
PITTSBURGH 1, PA.
Plants: Pittsburgh & New Brighton, Pa. • Bridgeport, Conn.

MIDVALE-HEPPENSTALL COMPANY
NICETOWN, PHILADELPHIA 40, PA.

the principle of passing magnetic fields through the melt to produce a stirring action.

The stirrer's main application is with arc furnaces of 30 to 200 tons that are required to produce high-alloy, high-quality steel. Magnestirrer achieves the required uniformity in the melt, reduces the length of time per heat—giving increased production—and effects better recovery of the alloys introduced into the melt.

Two such systems are in operation. Each consists of a rotating two-pole d-c magnet, six ft in diameter and weighing 17½ tons, driven at 25 to 60 rpm. The magnetic field generated is swept through the molten bath of steel and produces a series of eddy currents. The eddy currents in turn react with the magnetic field of the stirrer to move the steel. The drive system is a steel mill type, totally-enclosed adjustable-speed motor.

The entire system is mounted directly under the furnace and, to insure adequate cooling, a forced-air system is included as well as temperature-sensing system to warn of impending furnace burn-through.

Modern developments have placed such rigorous requirements for uniformity of mixture and temperature in the special steel melts produced by electric furnaces today that the steel industry is realizing a need for better methods of stirring the melt.

GAS DENSITY CELL

△ The Type 35 gas density cell, an instrument which provides continuous precise measurement of gas density in pounds per cubic foot, has been introduced by The Foxboro Co. The instrument produces a differential pressure directly proportional to density. This measurement, combined with a pressure differential across a primary device, makes it possible to determine mass flow of gas.

Gas at line static pressure is introduced into the sampling chamber. This pressure is measured at a high pressure differential connection. Rotating in the chamber is a hollow spinner driven at a constant 3600 rpm by a synchronous motor. A magnetic coupling between the motor shaft and the spinner shaft, separated by a nonmagnetic seal cap, makes the chamber leakproof.

Centrifugal force produced in the spinner tube creates a suction which draws gas through the tube from an opening at the center of the spinner. This suction pressure, varying directly with the gas density, is connected from the hub of the spinner to the low pressure differential connection. The differential between the high and the low pressure is a true index of gas density.

The differential pressure is measured by a standard differential pressure instrument which may be located up to 50 ft away. This measurement is combined with that of the differential across a primary device, and integrated to give mass flow applicable to the gas industry. Or, the flow rate and density differentials may be measured by close-coupled transmitters which signal pneumatic computers to obtain mass flow necessary in control of plant processes.

The gas density cell measures densities up to 7.8 lb per cu ft. It weighs 48 lb and is 9½ in. in diameter at the flange by 15 in. high. Vertical and horizontal mountings are available.

OPERATIONS RECORDER

△ Panellit Division Information Systems, Inc., announces a new transistorized high speed sequential event recording annunciator which utilizes all solid state components except in the printer. The Panastat THOR VII is designed for monitoring variables in all continuous process industries, and has a number of exclusive advantages.

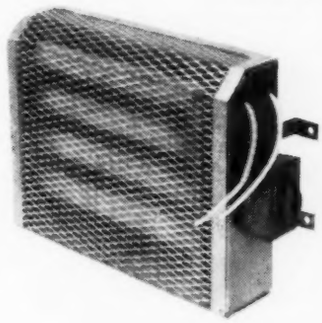
All alarm points going off-normal or returning to normal are printed in time sequence even if only one millisecond apart. Alarms can never be lost or scrambled even if the memory storage is filled. Yards of useless blank tape accumulation are eliminated because the paper tape advances only after each printing.

Patented 2-color digital printout uses one color to record off-normals and a different color to record the return to normal. A unique off-normal summary informs operator of all points still in alarm in their numerical order.

The entire system can be checked out quickly by activating an exclusive test feature which puts all points into alarm, returns them to normal and lists them in numerical

Guyan®
HEATERS

WALL TYPE



FOR CONFINED AREAS

ALSO AVAILABLE IN FLOOR TYPE

RUGGED
and ECONOMICAL TOO!

WHEN the space is hard to heat — such as a crane or locomotive cab, a pump house or small office — a GUYAN natural convection heater is the answer. It is a DEPENDABLE, LONG-LIFE HEATER consisting of corrosion-resistant aluminum chromium wire — wound on ceramic forms — and mounted within expanded steel housings.
GUYAN Heater Units are ruggedly built to stand the hard service that is customary in tough industrial applications. Available from 1,500 thru 7,500 watts for 110, 220, 440 volts DC or AC. Priced right — more economically than you might think — and lower than you can make your own. Write for complete information.

GUYAN MACHINERY CO.
LOGAN, WEST VIRGINIA

Guyan®
HEATERS

order. Further reliability is provided by a malfunction warning lamp and a self-failure analysis which identifies a malfunctioning part in just 2 sec.

Printouts during the operator's absence are immediately apparent upon his return because they are indicated by a lighted lamp with pushbutton reset.

PYROMETER CONTROLLER

△ Now available with General Electric Co.'s HP-30 series pyrometer controller is the new Type 510 digital set point unit which provides greatly improved measurement sensitivity and a method of easily reproducible set point adjustment. The instruments are especially suitable for applications requiring precise temperature control.

When used with the new set point unit, the HP-30 controller acts as a null-indicator rather than a temperature indicator. It provides excellent sensitivity, measuring only temperature deviations from the set point, and detects changes as small as 0.25 F. The set point unit is easily adjustable in 0.01 millivolt steps. For example, this corresponds to temperature changes of 0.3 F for iron-constantan thermocouples. Use of the controller and set point unit package is ideal in operations where precise temperature control is necessary, according to G-E engineers.

The set point unit uses a stable silicon diode voltage source and its output is adjusted by a digital dial. The desired set point is selected in millivolts, corresponding to the temperature, by use of the digital dial and a range suppression switch. The unit has a temperature sensitive resistor providing cold junction compensation.

Accuracy of the set point unit is ±0.25 per cent of total span including linearity hysterisis; ±10 per cent line voltage change, and ±10 C ambient temperature change. Its ambient operating range is 0–140 F.

Set point ranges include: Iron-constantan, type J—10–20/18–28/-26–36/34–44 millivolts; Chromel-Alumel, type K—18–28/26–36/34–44/42–52 millivolts, and, Platinum-Pt. Rhodium, types R and S—0–10/-8–18 millivolts. The digital set point is adjustable from 0–9.99 millivolts within any of the ranges.

SPEED REDUCERS

△ The efficiency of high ratio worm gear reductions has been increased through the use of a helical and worm gear double reduction combination in the new HUF and HDF speed reducers recently introduced by the Cleveland Worm & Gear Div., of Eaton Manufacturing Co.

The units are available with output shafts extending either upward or downward. The helical and worm gearing run in a large capacity common oil bath for effective cooling and lubrication. HDF-type units, which have the downward output shaft extension, use a dry well construction to avoid the hazard of oil leakage.

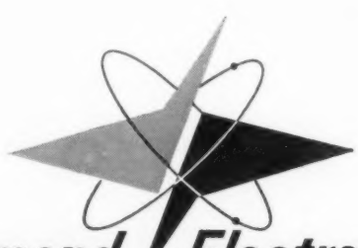
The helical gears are hobbed, crown shaved and flame hardened and have been designed to withstand the same momentary overload of 300 per cent of rated load as the worm gearing, thus insuring a balanced design. The centrifugally-cast bronze worm gears employed in the HDF-type units are either solid or have rims welded to cast-iron

New Hawk 401 Utiliscope

An Unprecedented Closed Circuit

Impressed by the potential value of closed circuit television but *depressed* by reports of high initial cost, expensive maintenance, constant requirement for difficult adjustments, and general unreliability? Then listen . . . to an unprecedented proposition from the world's oldest manufacturer of industrial closed circuit television: Indoor or outdoors, in any kind of weather with practically any degree of illumination, Diamond Electronics' all new Hawk 401 Utiliscope is *guaranteed on a money-back basis* to provide a sharp, clear picture of just about anything . . . perimeter barriers, gates, transfer points, loading docks, construction areas, vehicular movement, rooftops, hazardous areas . . . all from one safe, comfortable and convenient location. The Hawk requires no special housing, no special power supply, no special adjustments for changing light and weather conditions. Just plug it into an ordinary 110 V outlet and forget about it.

See for yourself. Call, write or wire and we'll arrange a demonstration within the week.



Diamond Electronics

Diamond Power Specialty Corporation • Lancaster, Ohio

hubs. In HUF types, worm gears are either centrifugally cast onto a cast-iron hub that has a double row of lugs for mechanically keying the bronze ring to the hub, or have flanged-type rims bolted to the hub. Flame hardened alloy steel worms are cut integrally with their shafts. Aluminum or plastic cooling fans are mounted on the high speed pinion to insure adequate cooling of the heavily finned cast-iron housings. Shafts and bearings throughout are sized and located to withstand high overhung loads.

REFRACTORY

△ A fusion-cast refractory designed to be welded into place has been developed to combat industrial abrasion problems.

Introduced by Corhart Refractories Co., a subsidiary of Corning Glass Works, the new product is called Corhart ABR.

According to the manufacturer, the product is the only abrasion-resistant refractory that can be welded into place. This means installation is quicker, easier and less costly.

Each ABR shape contains a partially exposed steel lug which is arc-welded directly to the shell or structure to be protected from abrasion. There is a relief area on the face of each piece to facilitate tight flush-mounting. Standard shapes used and welding gives each piece a positive, lasting grip on the superstructure.

Corhart said the physical characteristics of ABR enable the product to withstand abrasive attack longer than other materials conventionally used in coke chutes, ore chutes, gas washers, clinker chutes, belt scrapers, pipe liners and other areas.

The material can be used in most areas where abrasive attack occurs as a result of moving bulk materials, including coke, sinter, clinker, ore, taconite and hard pelletized items. By placing the refractory in maximum wear areas, the entire system can be balanced to provide longer continuous runs.

Corhart ABR is manufactured by the Electrocast method, a patented process first developed to produce super refractories for the glass industry. The process involves melting zirconia-alumina-silica to a liquid state in an electric arc furnace at temperatures exceeding 3200 F. The material is then cast into the desired shape. The result is a dense interlocking crystalline structure offering superior abrasion-resistant properties.

permits...

Proposition In Television...

CAR SPOTTERS

△ Link-Belt Co.'s newly-redesigned 5-hp capstan-type car spotter features increased load ratings of 6000-lb starting pull and a 3000-lb running pull.

These high-capacity spotters have compact, impact-resistant, all welded steel housings designed to withstand shock loads and operating abuse. Welded steel feet at each corner of the housing permits a square bolt-hole-center mounting for any position.

The heavy, abrasion-resistant steel capstans properly proportioned for maximum traction with minimum effort assure longer capstan life. When wear does occur, the capstan can be resurfaced right in the field. A major improvement in the spotter's design is the cam-type backstop which replaces the

Immediate Delivery--

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BEARING SERVICENTER

With over 50,000 different items regularly carried in stock--you can be sure of *immediate delivery* on every order, large or small.

BERRY BEARING COMPANY

DAnube 6-6800

MICHIGAN AVENUE at 26th STREET
Chicago 16, Illinois

old style ratchet and pawl assembly. This new feature holds cars on an incline in the event of a power failure. Anti-friction bearings and precision gears assure many years of maintenance-free operation.

Two models are available: Model 55A with a foot-mounted motor on a bracket fastened to the housing and Model 50A which has a flange-mounted motor as an integral part of the unit. Both types are also available with steel frame carriages and wheels for easy portability.

GEARMOTOR

△ Designed for direct connection to the driven machine, a new footless single reduction gearmotor has been added to the U. S. Electrical Motors Inc., Syncrogear line.

This motor, designated the Type GH Unimount Syncrogear, is available with NEMA style C or D brackets in 9 and 10⅞-in. face plate diameters respectively. The new Unimount Syncrogear retains the same quality features of the foot mounted type, such as: asbestos protected windings, normalized castings, precision U. S. Motors honed gears and solid shank high speed pinions. U. S. Motors makes its own gears to assure accuracy.

All gears and pinions are crowned during the shaving and honing operation to assure the best surface durability and smooth, quiet operation. Only the slower speed gears dip into the oil reservoir, providing efficient lubrication without churning.

The GH Unimount is available from 1 to 5 hp, 230 to 780 rpm in dripproof, totally-enclosed and explosion-proof designs. Other U. S. Syncrogears are available from fractional to 75 hp, in many different speeds, configurations and mounting positions.

GAS CARBURIZED ROLLS

△ Gas carburizing by The Badall Co., Inc., provides an effective means of supplying deep case depths on unusually large steel rolls.

Equipped with three large vertical controlled atmosphere furnaces among the largest in industry. Badall is able to accommodate tubular steel rolls up to 48 in. in diameter by 24 ft in length.

Although gas carburizing, con-

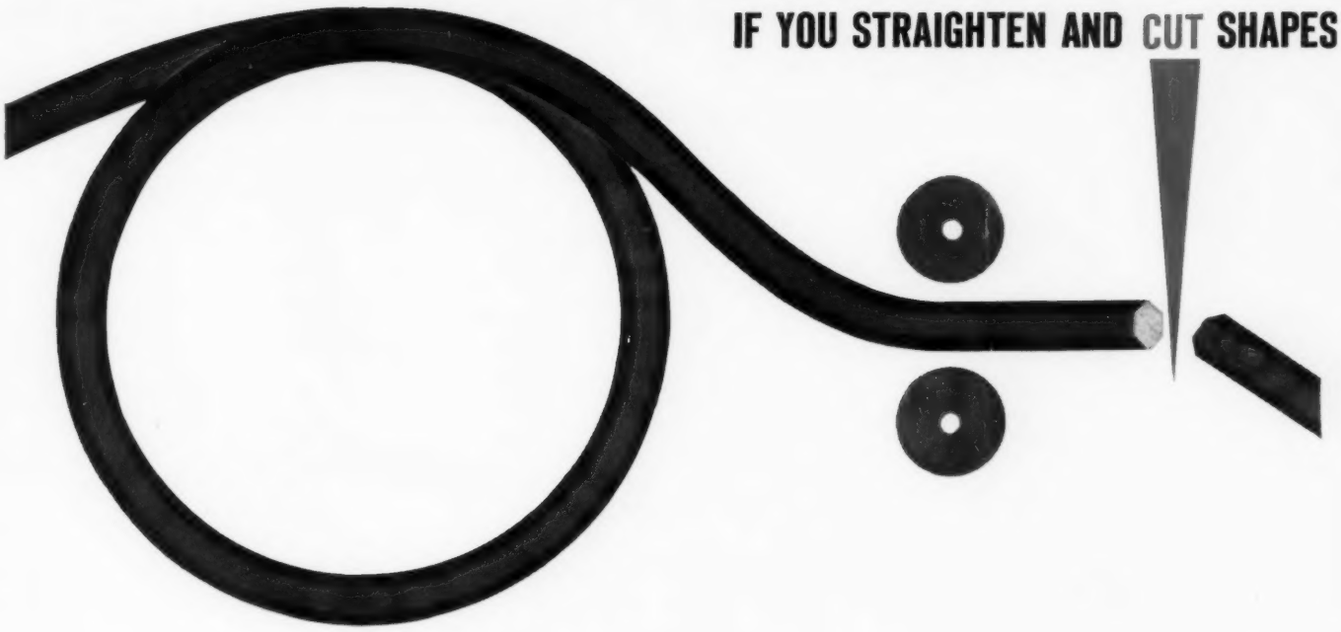
(*Continued on page 279*)

The Pringle Switch with "BOLTED" Pressure silver contacts operates quickly and easily under all conditions. Powerful **bolted** pressure is exerted on the closed contacts with practically no physical effort by the operator.

Find out more about this switch that does a perfect job in your applications every time it's called on to perform. Write for information. Pringle Electrical Manufacturing Company, 1912 North Sixth Street, Philadelphia, Pa.

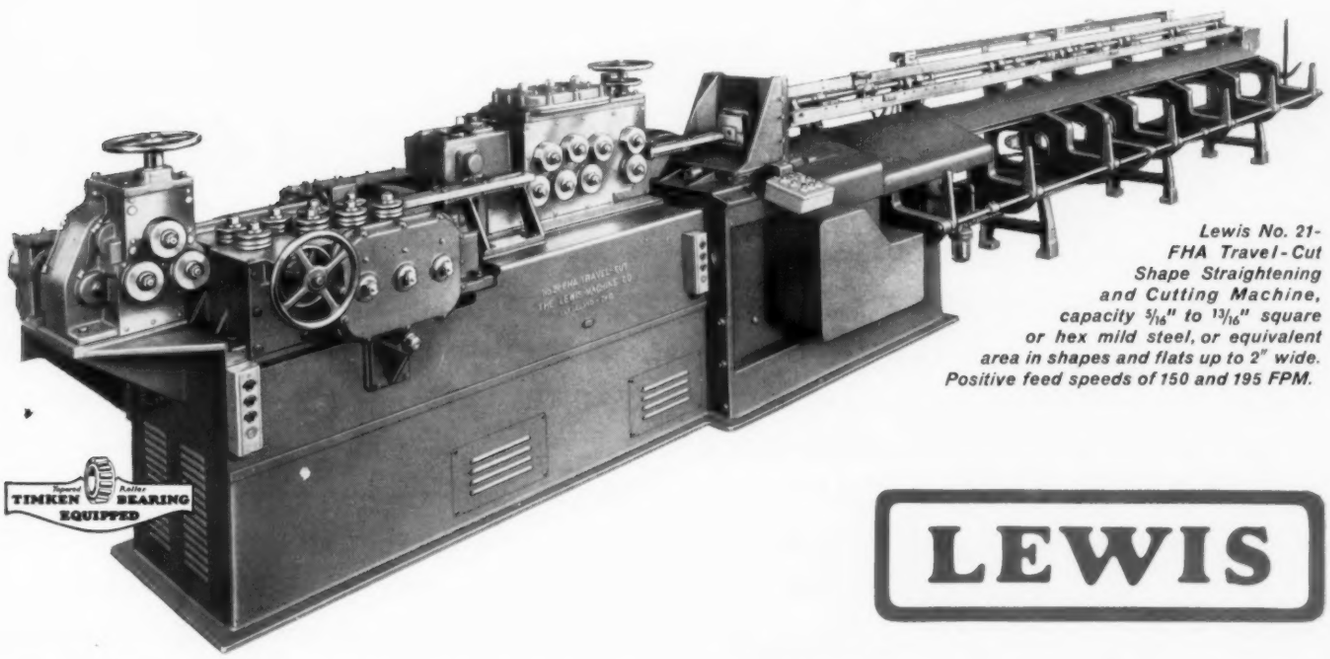
Pringle

IF YOU STRAIGHTEN AND CUT SHAPES



You can have higher production on accurate predetermined lengths . . . direct from the coil because of these features: ■ Improved low-inertia flying-shear cutoff. ■ Simplified electric trip mechanism assures positive tripping of clutch at high speed. ■ Independent gauging mechanism permits greater accuracy and simplifies changing of cutting length. ■ All roll shafts power-driven and mounted on roller bearings. ■ Adjustable features in Horizontal Straightener Housing and Vertical Housing to compensate for various stock widths.

The Lewis Machine Company manufactures over 50 models of straightening and cutting machines to handle round wire from .012" to 1" diameter and from 1/16" to 13/16" square, hex and flat. Write or call us for information on your requirements.

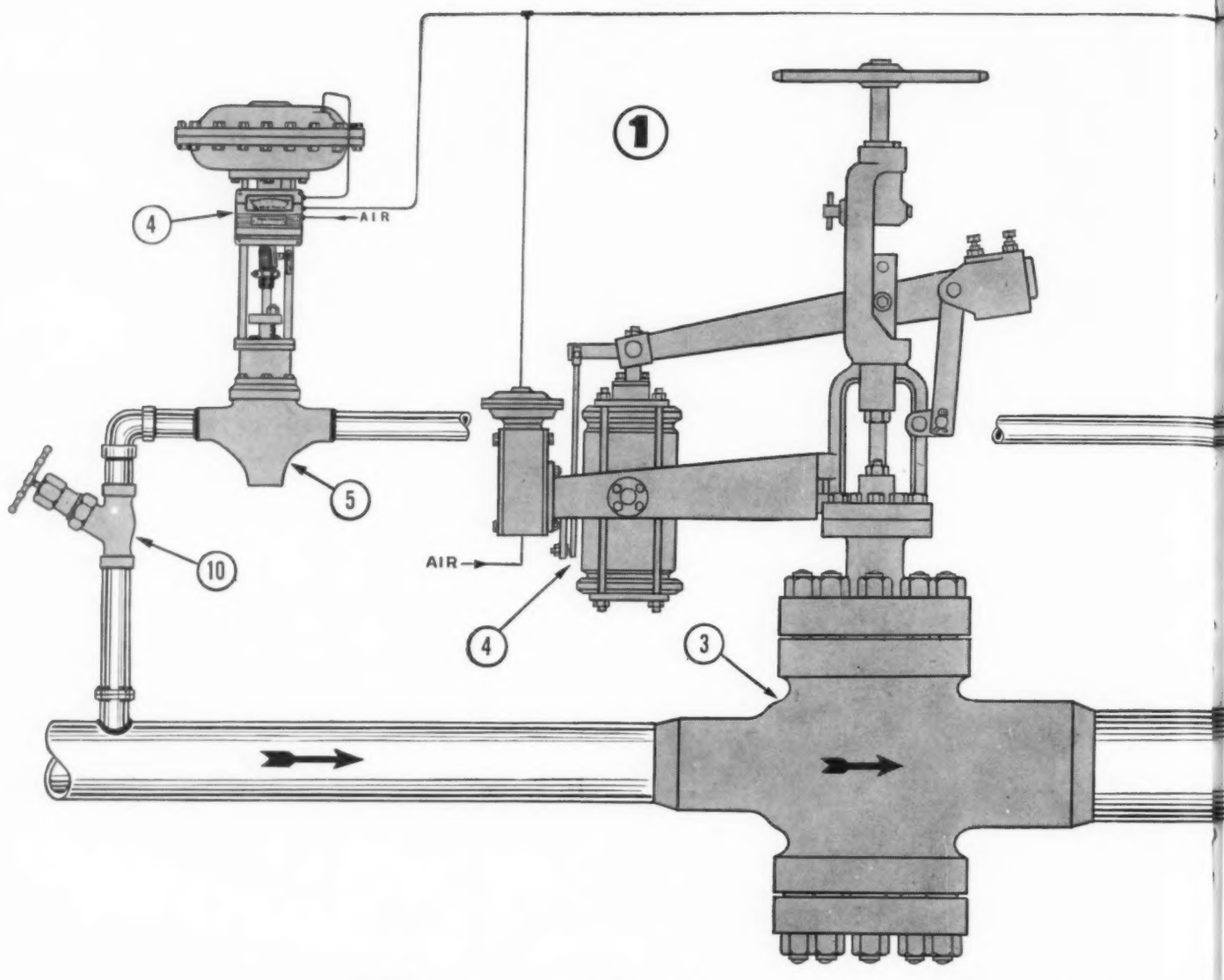


Lewis No. 21-FHA Travel-Cut Shape Straightening and Cutting Machine, capacity 5/16" to 13/16" square or hex mild steel, or equivalent area in shapes and flats up to 2" wide. Positive feed speeds of 150 and 195 FPM.

LEWIS

LEWIS MACHINE COMPANY • A Division of the Curtis Manufacturing Co. • 3441 East 76th St., Cleveland 27, Ohio, MI 1-3015

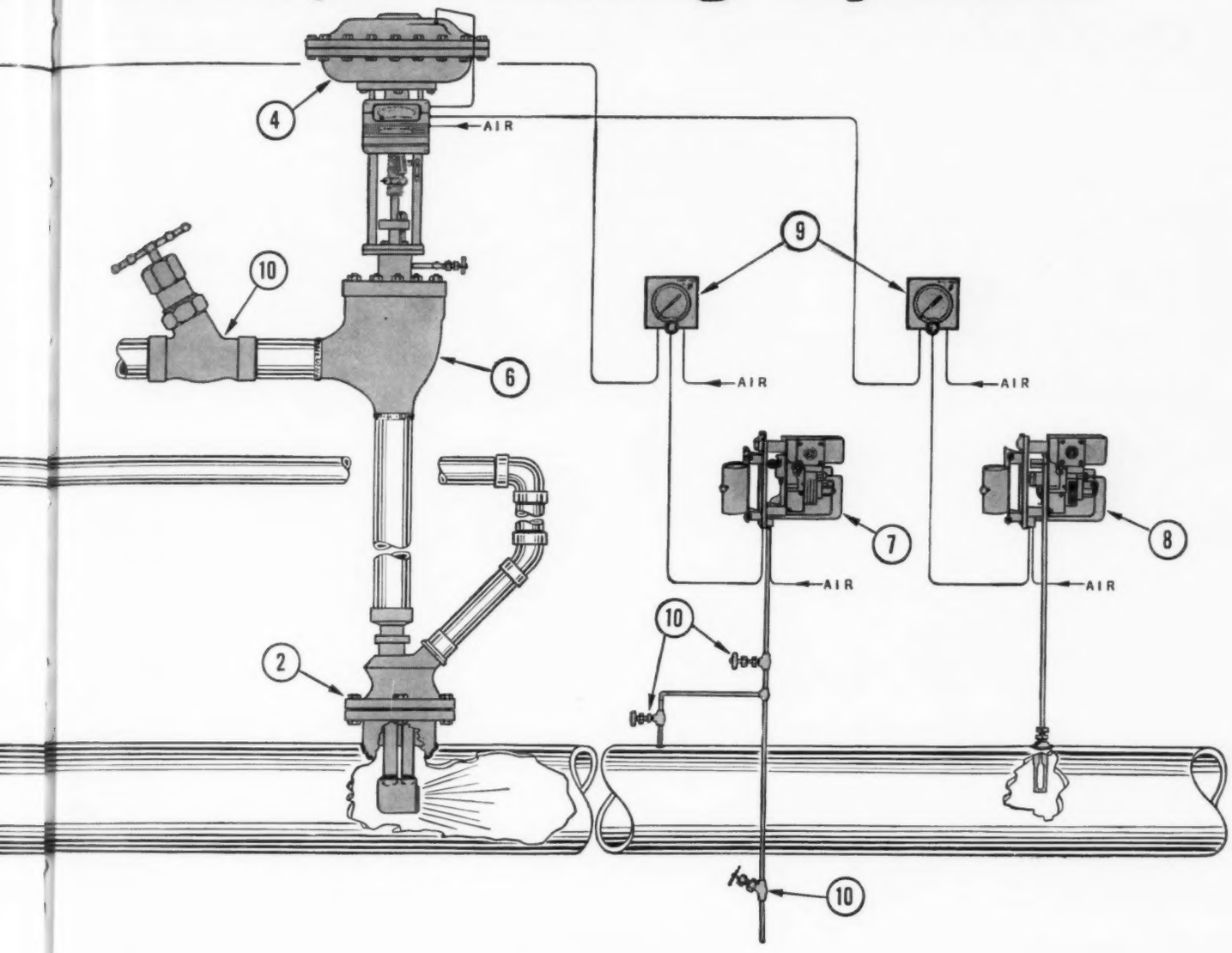
Pressure Reducing and



Complete package

1. SYSTEM ENGINEERING BY _____
2. STEAM ATOMIZING DESUPERHEATER BY _____
3. PRESSURE REDUCING VALVE BY _____
4. POSITIONERS AND DRIVE UNITS BY _____
5. ATOMIZING STEAM CONTROL VALVE BY _____
6. WATER FLOW CONTROL VALVE BY _____
7. PRESSURE CONTROLLER BY _____
8. TEMPERATURE CONTROLLER BY _____
9. CONTROL STATIONS BY _____
10. STOP AND BLOW-DOWN VALVES BY _____

Desuperheating System



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For full details on how a Rockwell-Republic pressure reducing and desuperheating system can benefit you, contact the Republic Engineer in your area. Or, write to Republic Flow Meters Company, Subsidiary of Rockwell Manufacturing Company, 2240 Diversey Parkway, Chicago 47, Illinois. In Canada: Republic Flow Meters Canada Ltd., Toronto.

REPUBLIC INSTRUMENTS AND CONTROLS
more fine products by
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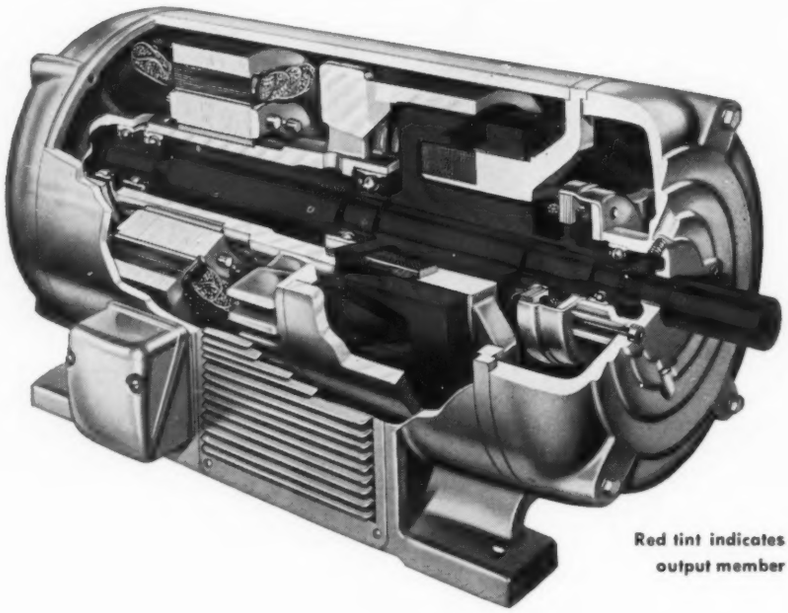
NOW— another FIRST by the Originator of Eddy-Current Equipment

NEW

DYNAMATIC®

Model 905 Ajusto-Spede® Drive



Red tint indicates output member

Extends Capacity Range to 15 HP in the Popular Quill-Type Design

The addition of the new model ACM-905 to the famous ACM-903 and ACM-904 lines of Dynamatic Ajusto-Spede Drives makes the desirable features of Dynamatic Quill-Type design available for many new applications.

Dynamatic Ajusto-Spede Drives provide controlled adjustable speed from an AC power source. Standard control features include on-off clutch control, infinite speed adjustment, constant speed regulation, and jogging. Any of a variety of special features may be easily and economically added to the standard control.

All Quill-Type models are available with either eddy-current, Dyna-torQ, or fail-safe brakes.

An Ajusto-Spede Drive, a control unit (either electron tube or transistorized magnetic amplifier), and a push-button station comprise a compact, easily installed, low-cost drive package.

Check these Ajusto-Spede® Advantages

- ★ **Infinitely adjustable speed from AC power**
- ★ **Simplified construction**
- ★ **Compact design**
- ★ **Wide speed range**
- ★ **Remote control**
- ★ **Stationary field coils**
- ★ **Excellent performance characteristics**

Send for Illustrated Descriptive Literature

EATON

EATON DYNAMATIC DIVISION MANUFACTURING COMPANY

3122 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

(*Continued from page 274*)

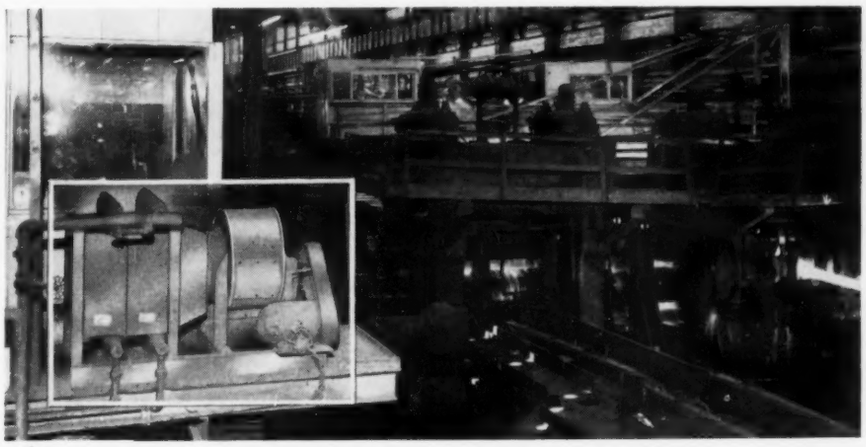
sidered a good high production tool, is usually used to obtain shallow cases up to 0.04 in., the Badall process supplies case depths up to $\frac{3}{16}$ in. or deeper for special applications, with no sacrifice of desirable core properties. This greater depth of case hardness is made possible by accurate furnace controls which enables Badall to closely control carbon levels.

The use of this process results in significant savings over pack carburizing rolls of this size to obtain the same case depth. In actual carburizing process, the roll is hung vertically in one of the furnaces in an elevated temperature-atmosphere containing carbon. After the carbon goes into solution in the steel, immediate violent quenching produces the desired hardness, usually in range of 90–100 Shore Scleroscope or Rockwell C 63–68 as converted. Badall facilities also include oil and refrigerated brine quenching tanks.

Book Reviews

"Temperature Measurement in Engineering," Volume II, by H. Dean Baker, E. A. Ryder and N. H. Baker, has been published recently by John Wiley & Sons, Inc., 440 Park Avenue South, New York 16, N. Y. The book contains 510 pages, 6 x 9 in., is cloth bound and sells for $13. This volume is divided into two parts, and in Part One resistance thermometer and the radiation pyrometer are thoroughly described and analyzed in a systematic manner. In the descriptive coverage a survey is made of the available components and standard unit designs; the analytical coverage consists of the development of a systematized design procedure similar to that followed in a purely mechanical design. Part Two is devoted to a selected assortment of actual problems. The peculiarities of an almost endless variety of situations are outlined and concrete examples are given of successful techniques worked out to perform measurements in these diverse circumstances. Each term or principle used is explained, equations are stated in form suitable for direct application. There are over 1000 references cited and numerous illustrations are included.

"The Use of Oxygen in the Electrometallurgy of Steel," by G. M. Borodulin, has been published recently by Permagon Press, Ltd., Headington Hill Hall, Oxford, England. The book contains 120 pages, 6 x 9 in., is cloth bound, and sells for $8.50. This book, translated from the Russian, examines the use of oxygen in electromelting of stainless, transformer, cracking, high-speed, chromium nickel structural, ball-bearing and high-carbon tool steel. It also contains information about the quality of metal melted with the use of oxygen, and about the technical-economic details of the process. The book tells how the productivity of electric furnaces has been considerably increased and, the cost of steel has decreased, while quality has improved. In certain steels rejects have been completely eliminated. Numerous tables, formulas, line drawings and photographs are used to explain the text.



to PREVENT OIL AND WATER LINE FREEZING AT GROUND LEVEL AROUND ROLL STAND FOOTINGS

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GRID HIGH VELOCITY BLOWER UNITS

WRITE for catalog No. 956, the complete GRID story.

GRID HIGH VELOCITY HEATING UNITS consisting of all cast iron Blast Heaters with belt driven, high speed blower. These special units operate on150 P.S.I. steam pressure at 450 degree Fahr. temperature. Air is raised from 10 to 20 degrees at inlet side to 150 degrees at discharge. Air discharge nozzles located below the platform force heated air in downward, angular direction to ground level. Air velocity 2500 to 2700 F.P.M. Air volume 4100 C.F.M.

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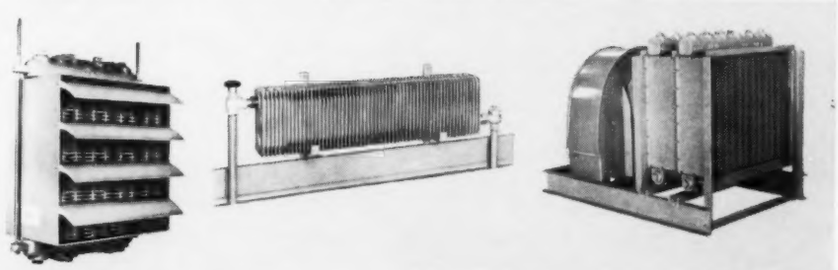
Manufacturers Since 1883 • WAUSAU, WISCONSIN

UNIT HEATERS RADIATORS BLAST HEATERS



Why do we say fulfills the promise

For single function or automated system... our Systemation concept is fitted to your actual needs

In crude definition, automation merely means "to make automatic." In implication, however, automation carries strong promise of low-cost production. It is in the area of lowering costs, some feel, that automation has most frequently missed its potential.

The engineering genius which can concoct sophisticated circuitry . . . join computers, primary detectors, instruments, processing equipment . . . too frequently overlooks the fundamentals of thorough *process knowledge* and such basic problems as the maintenance costs associated with automated systems.

Prudent investment of key importance

The *Systemation* concept is built around lowering *your* processing costs, increasing *your* productivity, improving *your* quality control. The starting point is not "what can be automated" but rather "what automation can be economically justified under your conditions of production."

Allis-Chalmers is thoroughly qualified to help you make *prudent* investment decisions about equipment and instrumentation.

Balanced judgment in depth

Long a supplier of control systems, a broad line of industrial processing and electrical generation, transmission, distribution and utilization equipment, A-C has an intimate knowledge of industrial processes. With the acquisition of Consolidated Systems Corporation last year, Allis-Chalmers extended its ability in the areas of data gathering, handling and utilization. CSC provides such experience acquired from more than 500 successful system projects.

Recently, Allis-Chalmers, Consolidated Systems and International Business Machines Corporation effected a nonexclusive mutual agreement relating to the production and marketing of automated control systems and processes.

For the typical system, Allis-Chalmers takes functional responsibility for the system using IBM data processing computer equipment, CSC specially engineered data conditioning equipment and instrumentation, and A-C basic and auxiliary industrial processing equipment. Now, Allis-Chalmers brings a balance of specialized judgments to bear on your problems . . . drawn on significant experience . . . to make major "contributions to the art" in many phases of *Systemation* and help you be sure before you invest.

Feasibility study shows opportunity

Your first step to Systemation *is a thorough feasibility study which spells out your opportunities for savings and puts a clear figure on the costs. Call or wire your nearest A-C office, or the Industrial Equipment Division, Allis-Chalmers, Milwaukee 1, Wis.*

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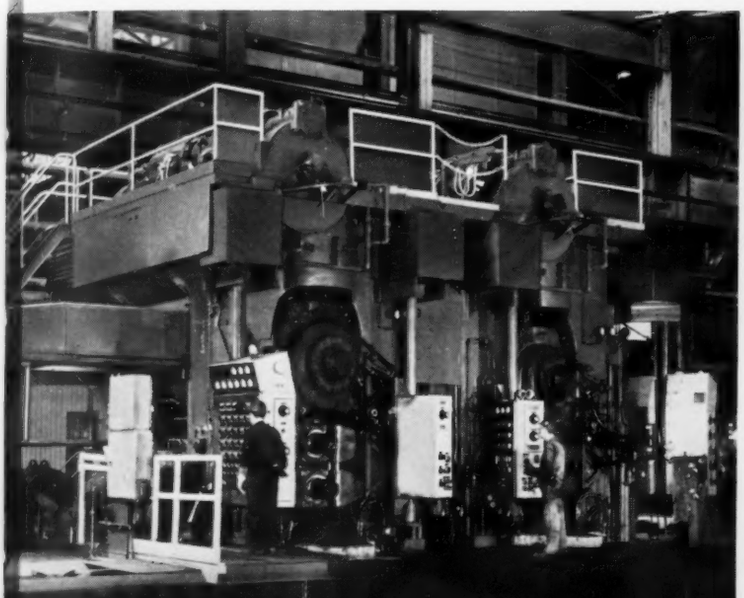
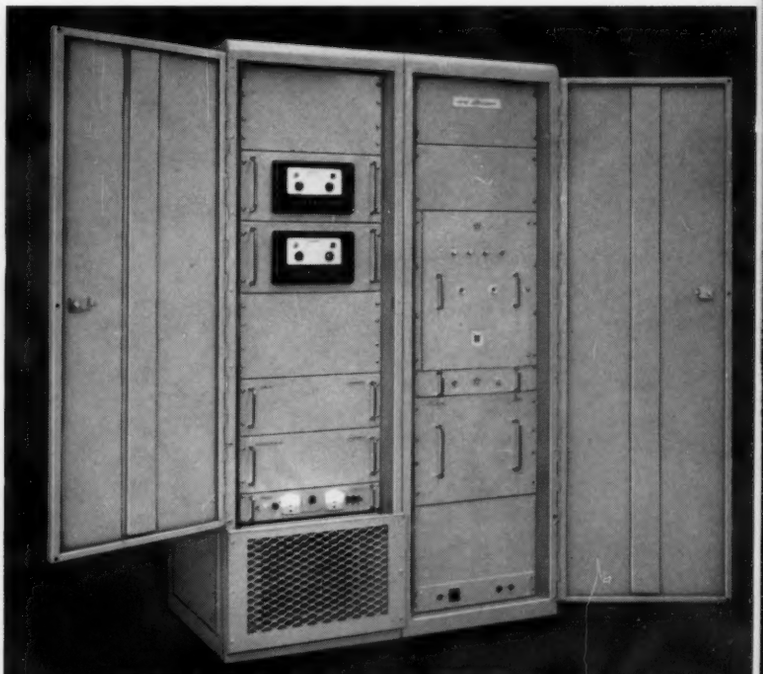
A-1531

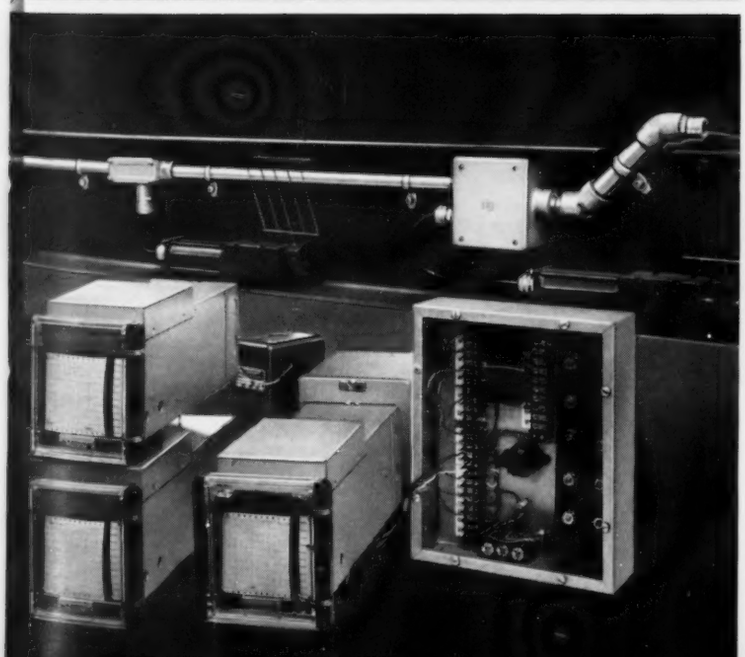
Systemation of automation?



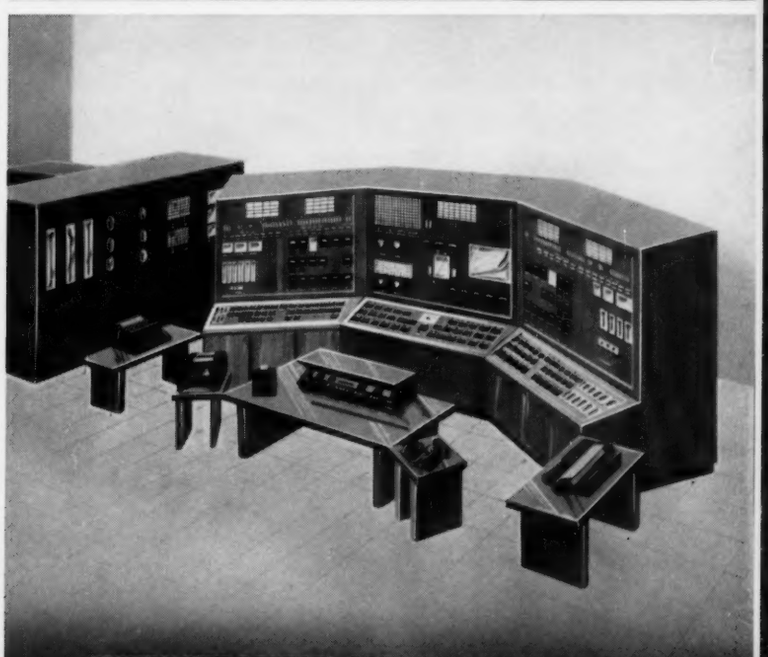
HIGH SPEED TEMPER MILL features include: automatic digital extensiometer to indicate strip extension (hardness pickup); automatic slowdown for rolling maximum length at rolling speed, yet prevent mandrel explosion or tail-end roll damage.



PRECISE AUTOMATIC GAUGE CONTROL for thin tin with automatic screw reset.



AUTOMATIC BED DEPTH CONTROL for traveling grate in GRATE-KILN iron ore pelletizing process.



CENTRALIZED CONTROL ROOM for generating plant using one computer to automatically control two units for start-up, operation and shutdown.

Our shoes come off like slippers

Just a turn of a wrench and off slides the shoe—and only the shoe. No loose hardware, no screws, bolts or nuts to lose. Shoe removal is really simple on Clark Brakes.

Replacing them is equally simple. Shoes are symmetrical, identical—fit either side, either end up... a Clark exclusive. Unique, heavy-duty shoe fastening knuckle provides shoe self-alignment and permits shoe replacement from either side.

This is only one example of how simple maintenance was designed into this "mill man's" brake to do a better job on the job. Try a Clark Brake on your next installation and see for yourself. 61MB1

HERE'S WHY CLARK AISE-NEMA BRAKES ARE FIRST CHOICE...

- Magnet hinged at top... dirt tends to fall through because widest part of rnagnet gap is at bottom
- Coil case easily removable without dismantling brake or even disturbing adjustments
- Epoxy encapsulated coils for better insulation, easier replacement
- Maintenance adjustment conveniently made from top
- Wheel and motor armature easily removable
- Self-aligning shoes assure even lining wear
- No special tools needed for maintenance or adjustment
- Eight sizes, 8" to 23" wheel diameters

THE CLARK CONTROLLER COMPANY

MAIN PLANT: CLEVELAND, 10 • WESTERN PLANT: LOS ANGELES, 58
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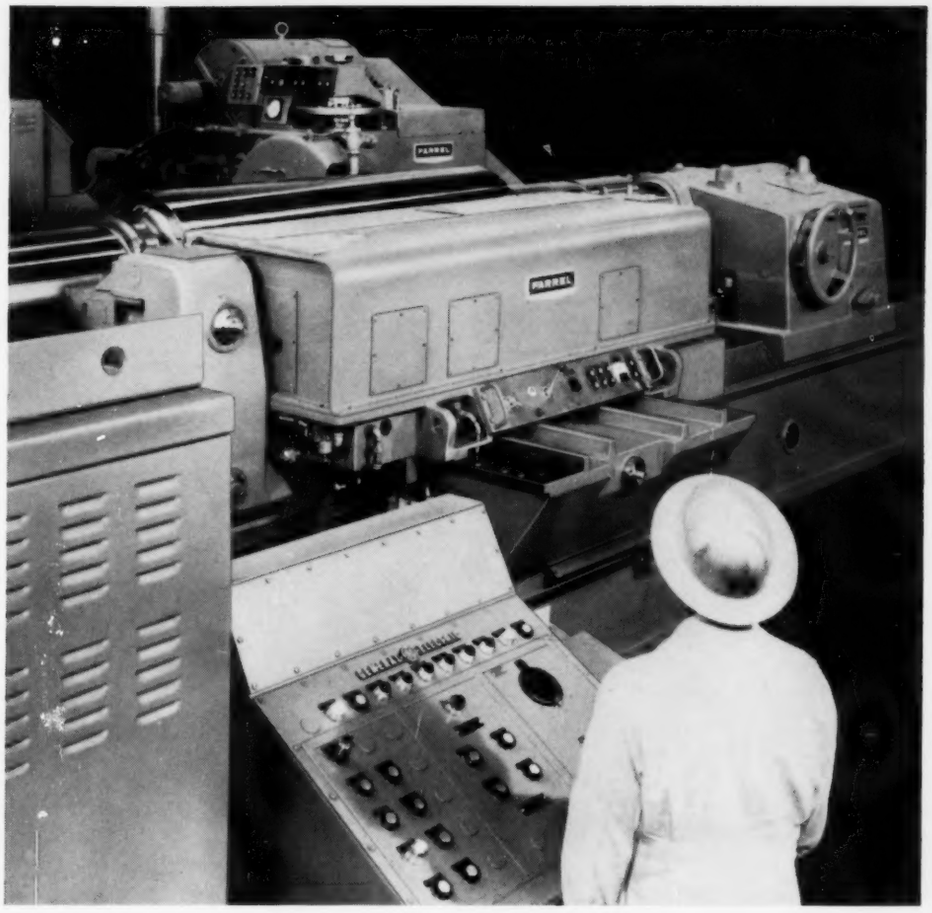

View of Farrel 60" heavy-duty, fully automated roll grinder, showing control console in foreground and probe table beyond.

NOW

your roll grinding can be AUTOMATED

(completely or partially)

Previously developed to the point where it could be set to accurately perform each of its functions, without manipulation by the operator, Farrel's heavy-duty roll grinder can now be fully automated. This brings a new dimension to roll grinding control and permits mill management to fix and maintain definite standards of regrind procedures.

Operating from standard one-inch tape, the automatic control will direct the grinder through a complete cycle, performing all operations necessary to refinish a roll. Thus the operator's responsibility is reduced to loading and unloading of the roll.

Accuracy of roll diameter and crown are automatically controlled, too, assuring minimum stock removal . . . longer roll life. The machine will also match exactly the diameters of paired mill-stand rolls, regardless of uneven wear.

Where *complete* automation is not needed, automatic control of individual machine functions can be provided. In short, the degree of automation delivered is dictated by individual requirements.

A Farrel engineer will be glad to discuss how tape-controlled roll grinding can improve your production method. Write or call today.

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y.
Sales Offices: Ansonia, Buffalo, Akron, Chicago, Los Angeles, Houston, Atlanta
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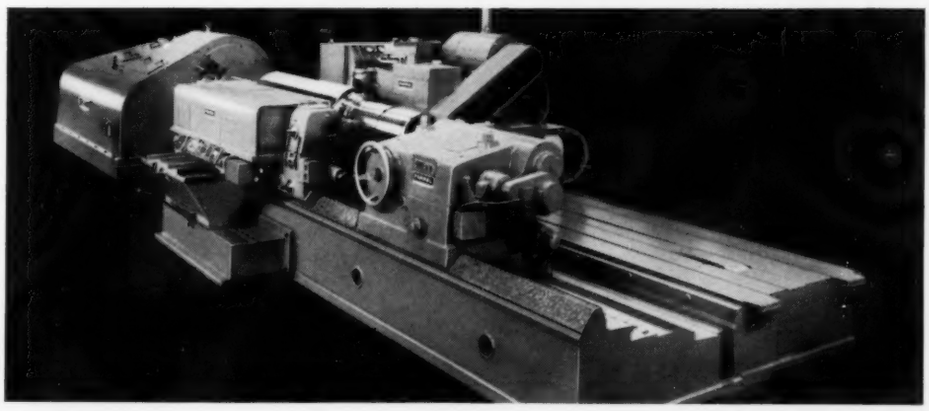
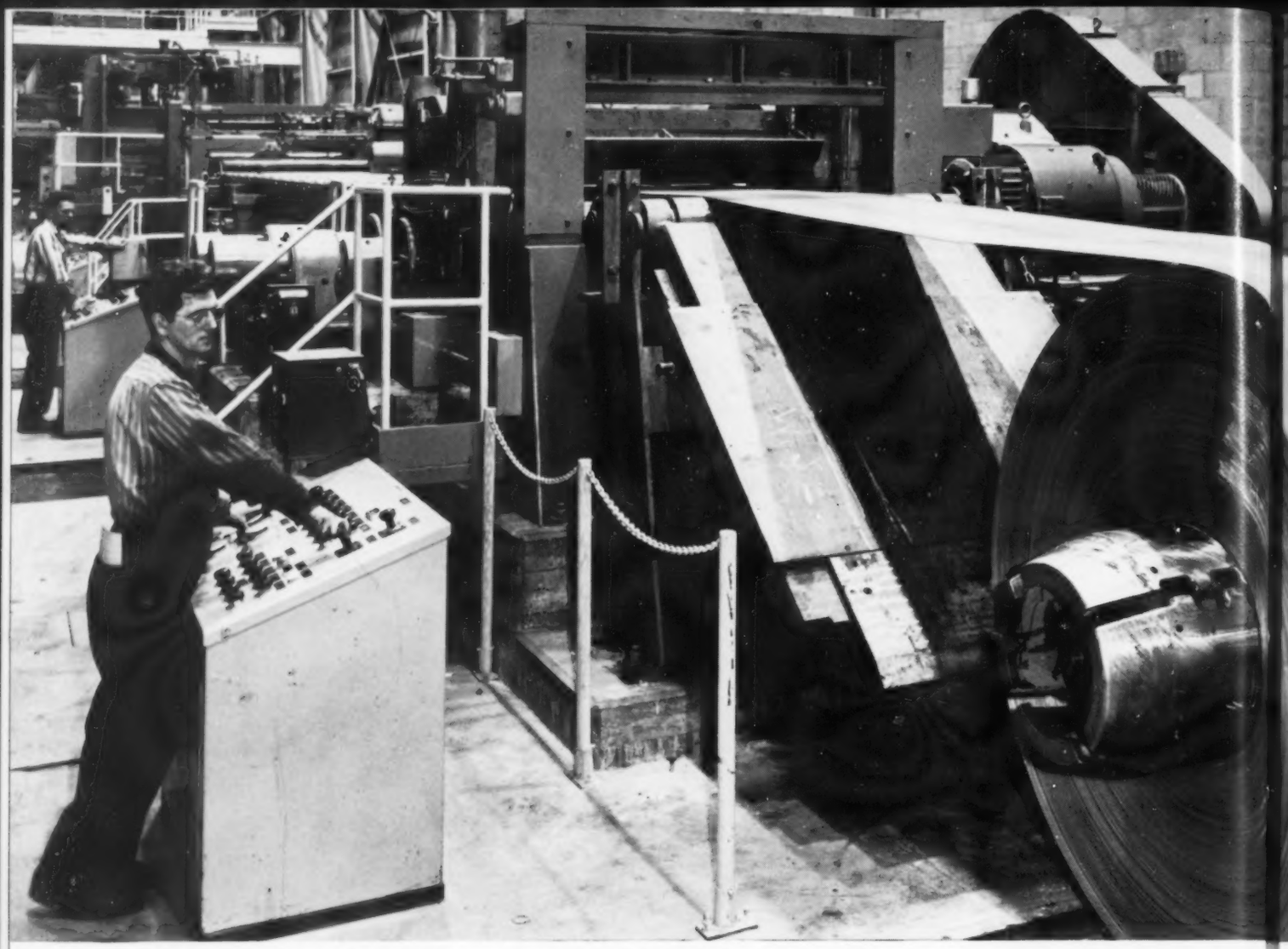
FARREL



FB-1226



Feeding in strip at the entry reel of a galvanizing line in Hamilton, Ontario.

SINGLE RESPONSIBILITY FOR DRIVE SYSTEM DESIGN PAYS OFF FOR CANADIAN MILL

The motors, controls, regulators and sensing devices which drive this continuous galvanizing line were integrated to produce a precise performance by one totally responsible source . . . Reliance Systems Engineering.

The drive system was designed to utilize sectional generators and control, thus achieving more flexibility to handle a broader range of products. Any or all units of the line consequently can be changed to meet new production demands. Positive speed sychronization between sections is achieved with Reliance transistorized VSRR magnetic amplifier regulators.

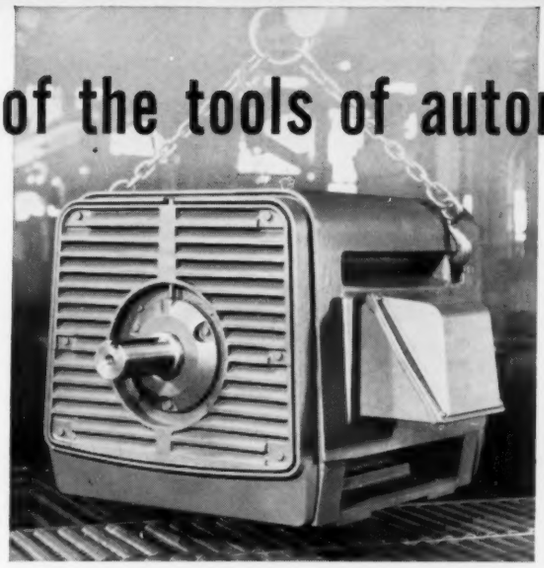
Close control of the line is demonstrated by application of modern sensing devices. When light gauge strip is coiled, for example, a Reliance "Tensitron", senses, establishes and maintains tension at pre-set levels.

Precise tension and tracking of the strip was quickly created and preserved throughout all 32 sections of the line . . . and uniform, high quality strip was produced. Reliance willingly accepted *total responsibility* for the planning and engineering of this processing line drive at the request of the mill . . . with logical and practical results.

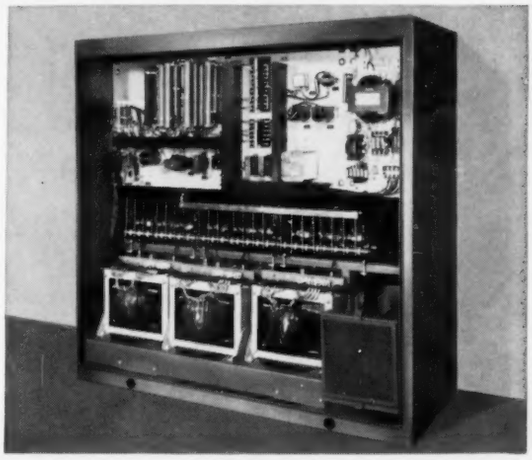
Reliance is ready and able to produce similar results for you. Your Reliance Systems Engineer can tell you even more about the advantages which can accrue to you through Reliance's Total Responsibility and Total Service. Call him —through your nearest Reliance office—or if you prefer, write us direct.

A-1687

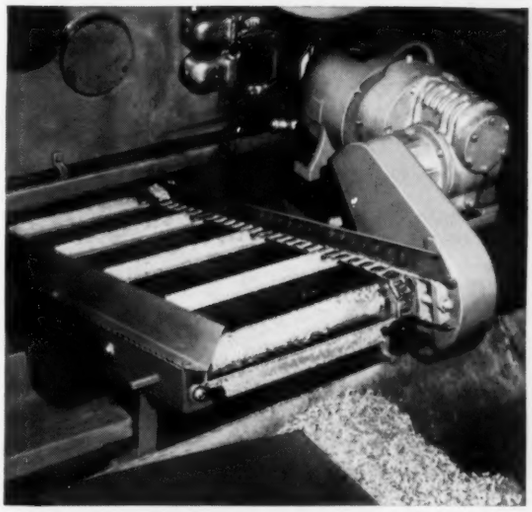
RELIANCE...
builders of the tools of automation



NEW DUTY MASTER D-5000 design brings you new standards in coolness, quietness . . . and more horsepower in less space. Frame dimensions that held 150 hp. now contain 300 hp. There is better heat dissipation from the frame itself. Air flows easily through the entire grilled end areas—exhausts through long, protected slots at the sides and bottom. New fingerless ducted rotor design means better cooling than any other previous motor. You get all famous Duty Master features in this new D-5000 . . . special lubrication design, drip or splash-proof and complete open motor protection. Bulletin B-2515.

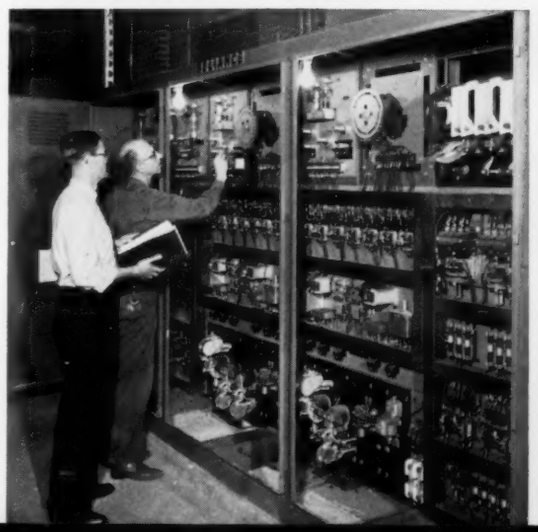


RELIANCE V★S STATATRON is a static powered drive for wide range variable speed from in-plant a-c. circuits, available from 1 to 200 hp. Instead of a motor-generator set, the Statatron uses silicon diodes and saturable reactors to rectify the current from a-c. to d-c. These work in combination with a transistorized power exciter to supply variable voltage. Statatron is compact—35% smaller than conventional units. Consists of only three components: Super 'T' d-c. motor, operator's station and control cabinet. Statatron is quiet—vibrationless and low in maintenance cost. Bulletin D-2508.



THIS MASTER GEARMOTOR drives a chip conveyor on automatic screw machine. The combination parallel and right angle reduction produces efficient low output speed at high torque—ideally suited to this operation. Features important here are its compactness and one piece construction, saving space and maintenance. This Master Gearmotor is impervious to liquids . . . splashing of coolant and any other outside contamination. Where the situation calls for gearmotors, this full line can cut your engineering and assembly costs . . . give you dependable performance. Bulletin E-2409.

TOTAL SERVICE is an integral part of every Reliance product, from engineering and start-up assistance to maintenance and renewal parts. The photo shown here is typical of a Reliance Service Engineer's on-the-job availability—for maintenance and consultation on knotty problems. Every Reliance Sales Engineering Office and Distribution Center—nationwide—gives you the attention and experience necessary to assure the top performance you expect from the Reliance equipment you buy.



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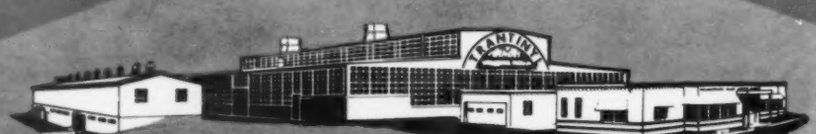


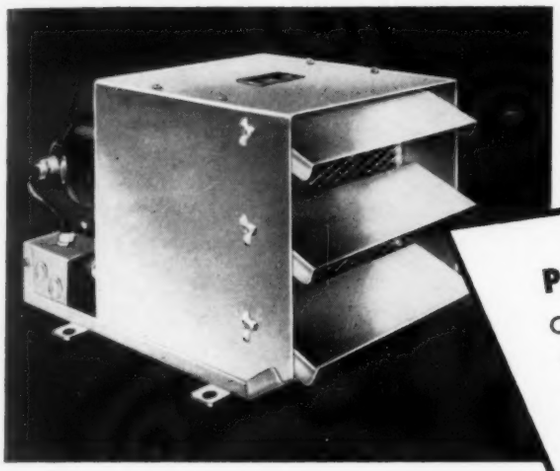
G-15

Sole Licensee to cast "TRANTINYL" for the Midwest, West and South: WAUNAKEE ALLOY CASTING CORP., Waunakee, Wis.

instant heat where

you want it...WITH THESE TWO

P-G CONVECTION HEATERS



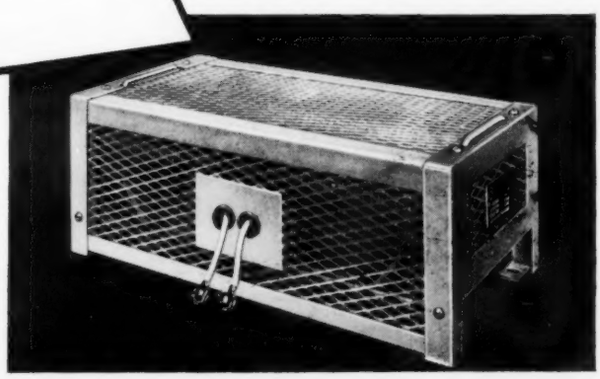
P-G Forced Convection Heater

Capable of moving a large volume of air with little noise. A 250 Volt D. C. Compound Wound Ball Bearing Motor of ¼ H. P. drives the fan. The heating circuit is controlled by a separately mounted 50-Ampere Magnetic Contactor energized thru a snap switch. The fan circuit is controlled thru a snap switch and contains a rheostat to vary the fan speed. Heating elements from 4 to 9 KW capacity, 230-250 Volts, D. C., are available.

P-G Natural Convection Heater

Ruggedly constructed, yet light in weight, they are easily portable by repair or construction workers. Ideal for permanent wall or floor mounting in crane cabs, etc. If a portable unit is desired, its disappearing handles may be used for ease in carrying. Made regularly in 3 to 6 KW capacity, 250 Volts, D. C.

TWO TYPES of HEATERS are available for industrial service. The heating element of both units is made of P-G Type T2, Chromium Steel Grids, which, because of their thin cross section, develop an unusually large heating area. A greater volume of warm air is so produced, and in addition, a more uniform heat distribution is obtained.



Write for BULLETIN NO. 600

P-G

ESTABLISHED 1892

THE **POST-GLOVER** ELECTRIC COMPANY

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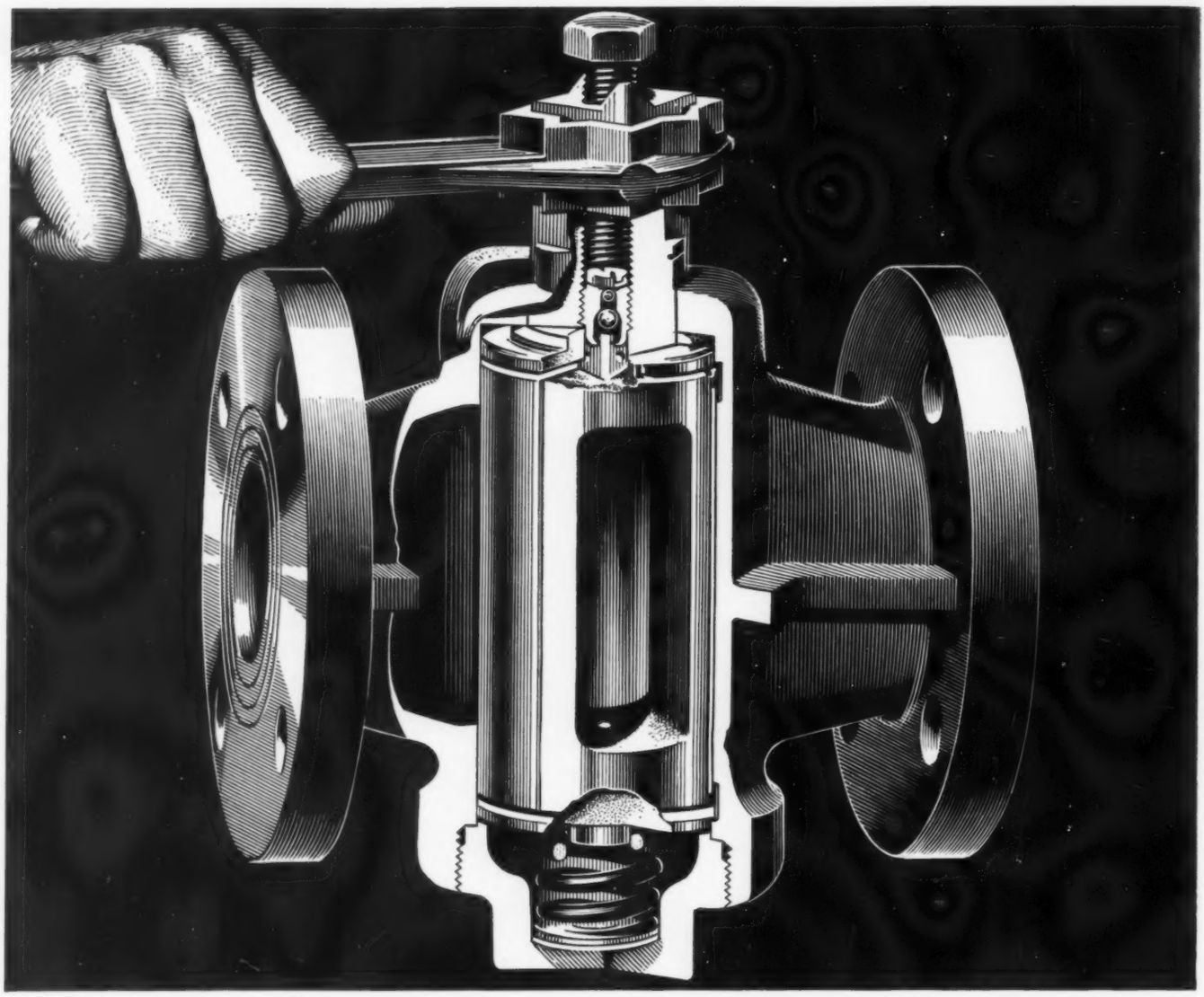
MAILING ADDRESS—Box 709, Covington, Kentucky



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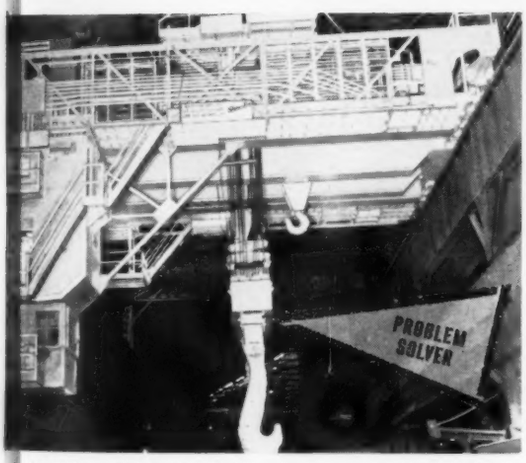

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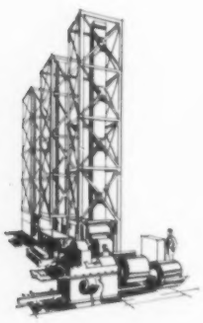

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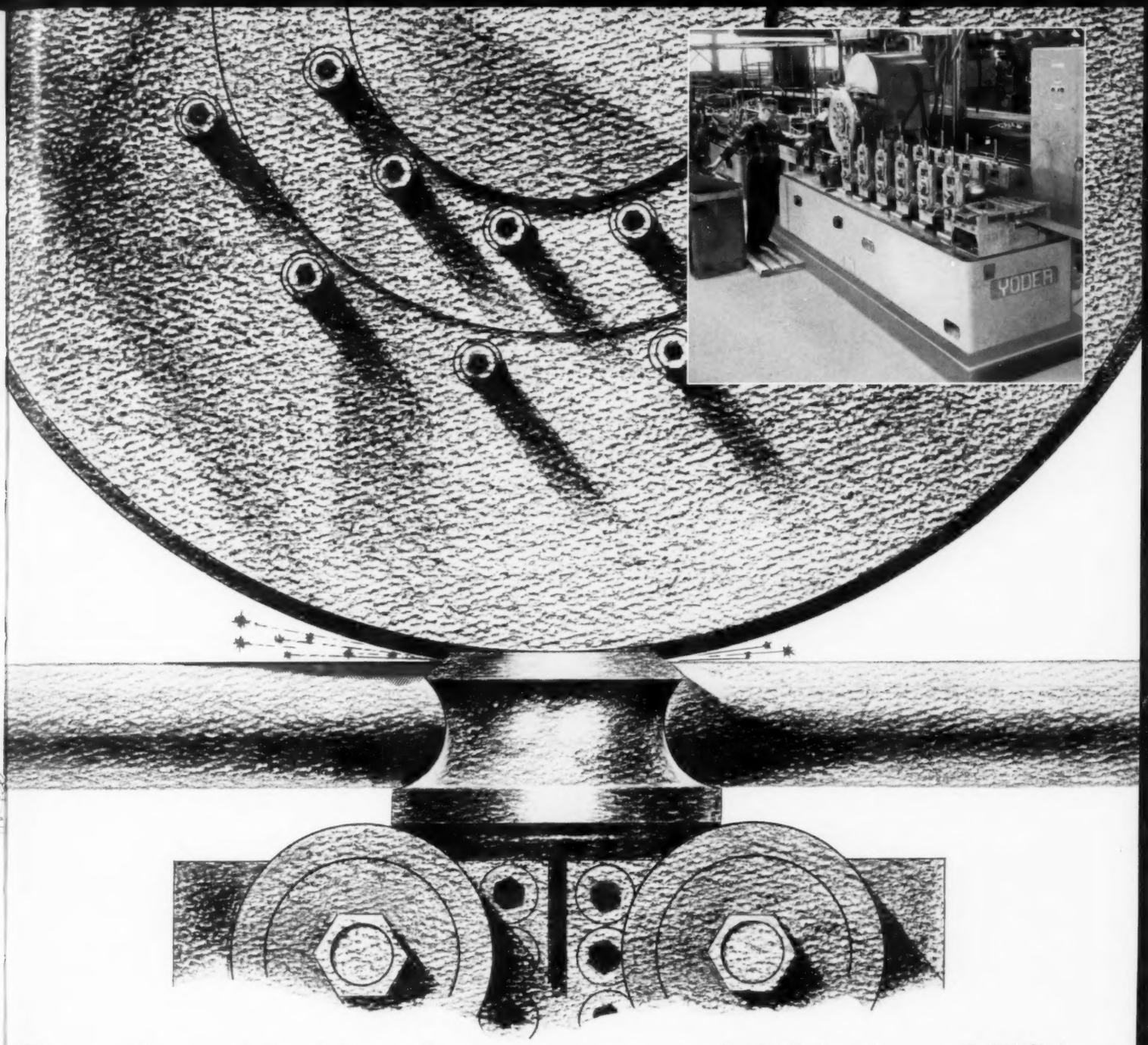

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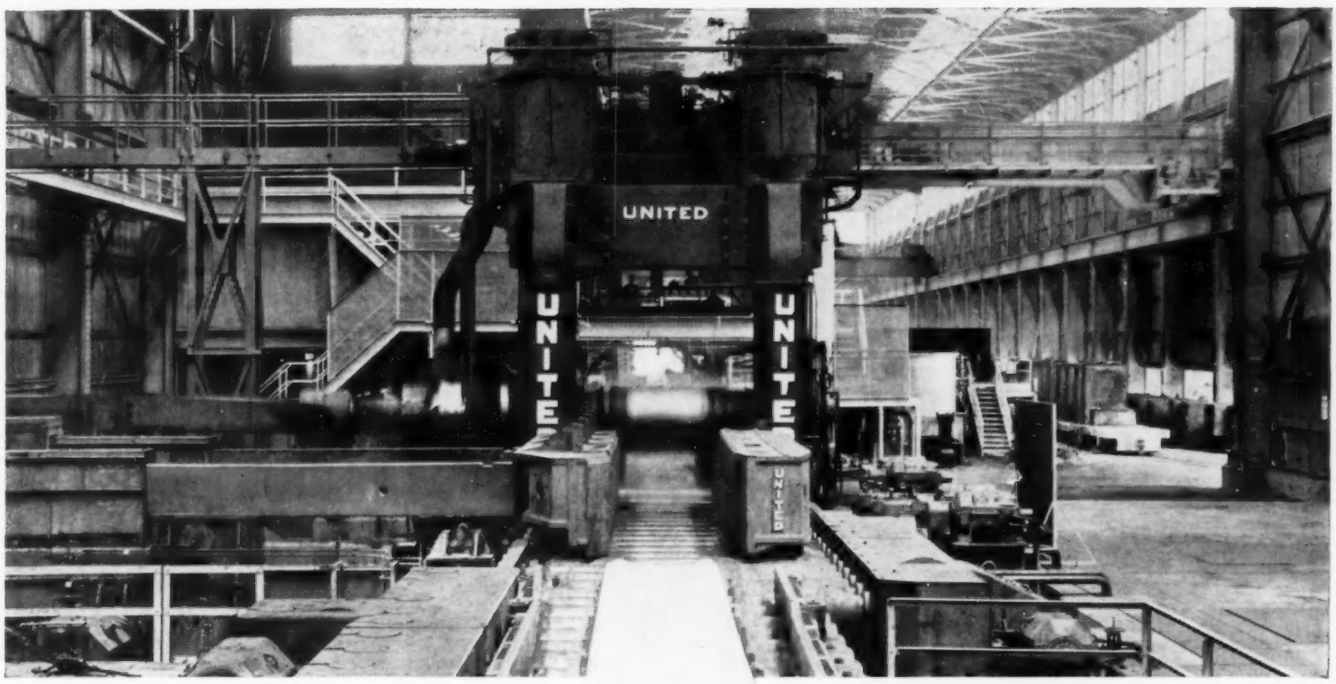

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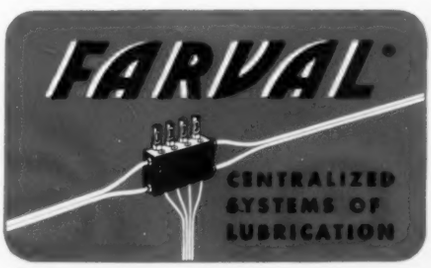

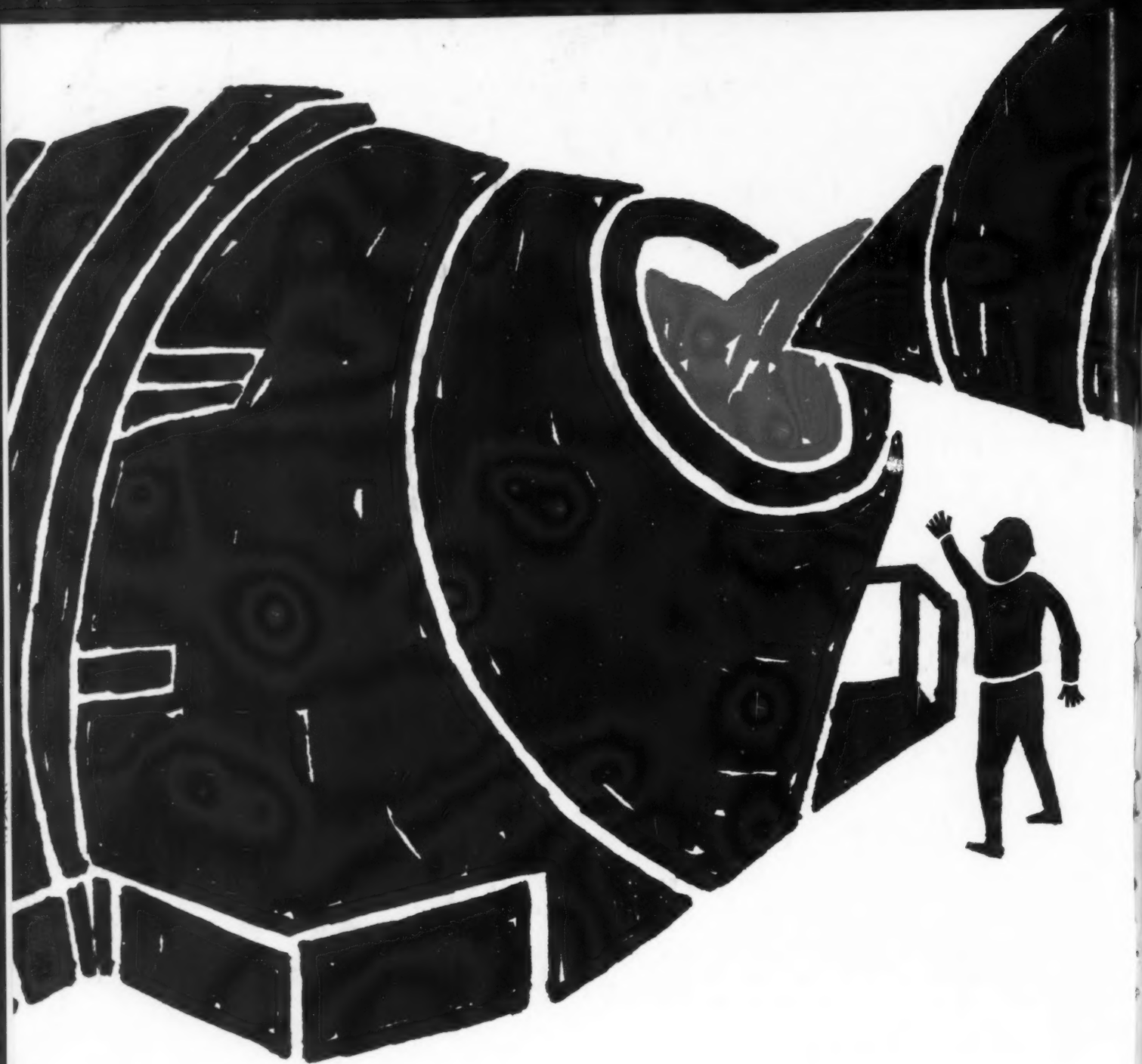

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